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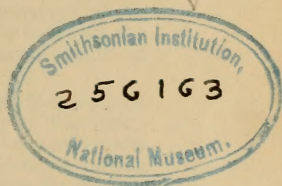
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THE

# AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. I.—*The Lecture Experiment with Liquid Carbon Dioxide*; by C. BARUS.

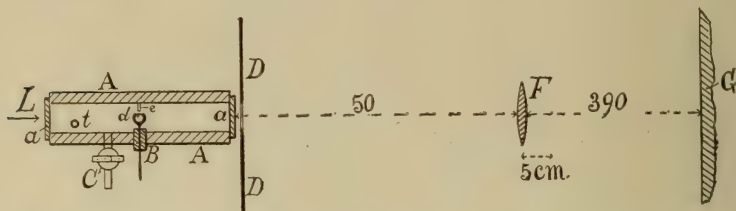
THE well-known glass tubes containing liquid carbon dioxide are present in almost every laboratory; but the full experiment showing the passage of the liquid through the critical temperature is none the less difficult to perform satisfactorily to a class. This implies that the experiment should be made safely and that the progress of the whole phenomenon should be clearly exhibited in a reasonable time. I will, therefore, venture to describe the following method, which has given good results and has thrown light on certain moot questions aside from its immediate purpose.

The experiment should be made with sunlight, for this facilitates manipulation (the room need not be darkened), enables the student to follow the work throughout and simplifies the optic principles involved. Care should be taken to choose a tube not quite filled with liquid, even at the critical temperature; otherwise the meniscus is lost too soon near the end of the tube. When submerged in a water bath, the effective difference of refraction between liquid and gas is relatively slight and only an imperfect and dark image of the tube and the meniscus is obtained on projection. Most of the light is apparently totally reflected away from the screen. As a special experiment one may even show a tube partially filled with water, side by side with the carbon dioxide tube, the former on projection exhibiting a remarkably sharper contrast between liquid and gas than the latter.

Hence the phenomenon is to be shown by heating the tube in an air bath. In this case the projected image of the whole



CO<sub>2</sub> tube is clear, and the demarcation between liquid and vapor broad and unmistakable even at a distance. Moreover the tube acts like a cylindric lens, a sharp silvery focal line being obtained both for the liquid and the gaseous part. The two focal lines, however, are not coincident, and hence, the *projecting lens must be moved back and forth* to obtain sharp images of the linear foci corresponding to the vapor or the liquid, respectively. This motion is considerable, two or more inches with the usual tube; and inasmuch as the inner ends of both focal lines terminate on projection in the visible meniscus, I have based the following experiment on this observation:



The figure shows the disposition of apparatus in sectional plan through the middle of the (vertical) CO<sub>2</sub> tube. *AaAa* is a trough with vertical wooden sides *A A*, about a foot square and placed about 2 inches apart internally. The ends, through which sunlight *L* is to pass horizontally, are closed by strips of thick plate-glass *a, a*, and the non-conducting lid (not shown) is removable. The center of one of the wooden sides *A* contains a hole and receives the perforated cork *B*, in which a horizontal rod or axle suitably holding the carbon dioxide tube *d*, is free to rotate. The tube being thus revolable on a horizontal axis, the small viscosity of the liquid as compared with water is well shown in projection by inverting the tube rapidly. The millimeter scale *e*, on transparent glass, is fixed in the same vertical plane with the tube and projected with it to measure the expansion. A thermometer is placed at some point *t*. A wide stop-cock *C*, inserted near the bottom of the trough, allows the admission of either warm or cold air, or if need be, of water. The thermometer is only needed to calibrate the CO<sub>2</sub> tube and scale in terms of temperature, by using the trough as a common water-bath. After this, the thermometer may be dispensed with, since the tube and scale constitute a more sensitive and a more easily visible instrument.

*D D* is an opaque screen with an aperture small enough to cut off all rays except those which pass through the lens *F*. The latter was of about 55<sup>cm</sup> focal distance, 10<sup>cm</sup> in

diameter, and placed about 65<sup>cm</sup> from the tube *d*, and about 390<sup>cm</sup> from the white wall or screen *G*.

The whole experiment is, as stated, made in full daylight. The displacement of the lens *F*, when focusing the liquid or the vaporous column respectively, is fully 5<sup>cm</sup> to 6<sup>cm</sup>, and curiously enough the extreme positions of the lens remain practically unchanged with temperature.

To supply the trough with warm or cold air, a bellows may be used and the current passed through a coil of lead pipe contained in a water bath kept at the boiling point. The length of coil is easily regulated so that the available current of air enters the trough between 30° and 40° C. The extreme mobility of liquid CO<sub>2</sub> makes these relatively high and unequal temperatures harmless, for in a serious case the liquid merely simmers, boiling at the lower end of the tube, while the bubbles condense before they reach the surface. When no current of air passes, the air bath soon cools without special appliances.

The surprising part of the experiment, to me, is the observation that the marked displacement of the lens *F*, necessary to converge the linear foci of gas and of liquid, does not vary appreciably (i. e., in an experiment conducted like the above) with temperature; one would naturally suppose that the highly compressed gas and the liquid so near the point of continuously merging into the gas, would show similar refracting properties; one would, in other words, expect to find two linear foci, one corresponding to the compressed gas and the other to the liquid, at a distance apart which would gradually vanish as the critical temperature is approached. This means that the necessary displacement of the lens *F* would grow continually less, becoming zero at the critical temperature. Yet such is not at all the case, as the following data show:

|                       |     |     |       |       |     |     |                 |
|-----------------------|-----|-----|-------|-------|-----|-----|-----------------|
| Temperature:          | 17° | 21° | 23·5° | 25·5° | 27° | 28° | 29°             |
| Column of gas left:   | 6   | 5   | 4     | 3     | 2   | 1   | 0 <sup>cm</sup> |
| Displacement of lens: | 5·5 | 5·5 | 5·5   | 5·0   | 5·0 | 6·0 | 5·5             |

the error contained being the uncertainty of focusing.

The linear focus due to the liquid column is of course real, and in case of my tube (external diameter 0·75<sup>cm</sup>, internal diameter unknown) lay about 3<sup>cm</sup> in front of the tube.\* (i. e.

\* The theoretical treatment of this case is cumbersome, involving as it does an extensive consideration of caustics in view of the wide aperture. The following data, however, illustrate the final result for parallel rays. If tubes be taken about 0·6, 0·8, 1·2, 1·4, 2·6<sup>cm</sup> diameter, and partially filled with water, the liquid focal line will as a rule lie within 1<sup>cm</sup> in front of the nearer wall of the tube. The corresponding focus for the gaseous column will be equally sharp but virtual and lie about 3, 4, 6, 9, 30<sup>cm</sup> respectively behind the liquid focal line, showing a



towards the screen *G*). The linear focus corresponding to the gas is however, virtual, for it is due to the refraction of a cylindrical shell of glass essentially of wide aperture, and lay about 3<sup>cm</sup> behind the tube (i. e. away from the screen *G*).

Unfortunately the only tube available was too full of liquid CO<sub>2</sub>, so that the liquid reached the top and could not be safely heated above 30° (critical temperature 31.1°); but I traced the total extinction of the gaseous focus, this being crowded out by the corresponding advance of the liquid focus quite into the top of the spherical end of the tube.

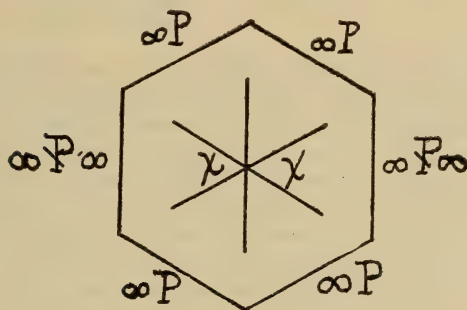
As soon as I get another tube I hope to push this experiment through to a definite conclusion. As far as I have gone, there seems to be small probability for the occurrence of real continuity between CO<sub>2</sub> gas and CO<sub>2</sub> liquid at the critical temperature. There is continuity between the liquid and *a gas which preserves the same molecule*, the same molecular structure as the liquid from which it issues. Doubtless at still higher temperatures the gas with the liquid molecule will break up into the true gas with the gaseous molecule, and the fact should be indicated by the sliding lens method sketched in the above experiment.

Finally it is desirable to specify a superior limit for the molecular weight of the liquid in question. The critical volume of carbon dioxide referred to the normal gas (0° C., 76<sup>cm</sup>) is .0043 (Cailletet verified by Sarrau). Thus the vapor density is 4.3 and the molecular weight by Avogadro's law, 123. This is singularly near C<sub>3</sub>O<sub>6</sub>, whose molecular weight is 132. The question thus arises whether C<sub>3</sub>O<sub>6</sub> gas above the critical temperature may not be as justly treated as a gas, as any other vapor under the ordinary conditions of vapor density measurement: for one may argue that the *intermolecular* forces which cause divergence from Boyle's law, etc., in CO<sub>2</sub> gas at the critical point, have in C<sub>3</sub>O<sub>6</sub> gas become *intramolecular*, giving the new molecule greater freedom of motion. In such a case C<sub>3</sub>O<sub>6</sub> would be the molecule of liquid carbon dioxide.

rapid march toward infinity. As in the above CO<sub>2</sub> tube, the liquid focus lay about 3<sup>cm</sup> ahead of the tube, the smaller refraction of this liquid is manifest, but so far as can be detected by the lens method, the gas focus does not appreciably differ in position from the gas focus for atmospheric air.

ART. II.—*Observations on Percussion Figures on Cleavage plates of Mica*; by T. L. WALKER, Leipsic.

REUSCH\* discovered that when a sharp-pointed punch is placed on a thin plate of mica and struck a sharp blow with a small hammer, a six-rayed star is formed on the mica plate. He also observed that one of the three lines forming the star is parallel to the clinopinacoid. The other two lines he described as parallel to the prismatic edges of the six-sided cleavage fragment of mica. These observations were confirmed and the investigation extended by Bauer,† who recommended the use of a large, somewhat blunted needle instead of the blunter instrument used by Reusch. He also emphasized the importance of the nature of the foundation on which the mica rests when the needle is struck. Reusch recommended a glass plate covered with a thin sheet of vulcanite. The accompanying figure represents a basal section of a mica crystal and indicates the directions of the different rays of the percussion figure.



These figures are fully described in all the larger text-books on Mineralogy, and although they all agree in asserting that two of the lines forming the star are parallel to the prismatic edges of the basal section, I find as a result of a large number of measurements that this is seldom if ever the case.

Since the prismatic faces of the micas form an angle varying only a few minutes from  $120^\circ$ , we would expect that all the rays of the percussion figure would form angles very nearly  $60^\circ$ . By measuring the angles in percussion figures of different micas great variations were observed. The following table shows measurements for about twenty specimens representing all the commoner species of mica and from widely

\* Reusch, Ber. Ak. Berlin, 428, July 9th, 1868.

† Pogg. Ann., 1869; also Zeitsch d. d. g. Gesellschaft, 1874.

separated localities. The letter  $\chi$  is used to designate the angle opposite the clinopinacoidal edge. The numbers given are averages of about half a dozen measurements in each case.

| Optical plane.                              |         |          |                              |                          | $\chi$          |
|---|---------|----------|------------------------------|--------------------------|-----------------|
| 1. <i>Muscovite</i> —                       | $\perp$ | $\infty$ | P $\infty$ (mica, 1st kind), | Murray Bay, P. Q. Canada | =52° 53'        |
| 2. " "                                      | "       | "        | " " "                        | Acworth, N. H., U. S. A. | =53° 20'        |
| 3. " "                                      | "       | "        | " " "                        | Locality unknown.        | =53° 42'        |
| 4. " "                                      | "       | "        | " " "                        | Hereroland, S. W. Africa | =54° 32'        |
| 5. " "                                      | "       | "        | " " "                        | Peterboro Co., Ontario   | =54° 56'        |
| 6. " "                                      | "       | "        | " " "                        | Marienbergl, Saxony      | 55° 32'         |
| 7. " "                                      | "       | "        | " " "                        | Utö, Sweden              | 55° 57'         |
| 8. <i>Lepidolite</i> —                      | "       | "        | " " "                        | Wolkenburg, Saxony       | 59° 12'         |
| 9. " "                                      |         | "        | ( " 2d kind)                 | Perm, Russia             | 59° 07'         |
| 10. " "                                     | "       | "        | " " "                        | Penig, Saxony            | 59° 45'         |
| 11. " "                                     | "       | "        | " " "                        | Mursinsk, Urals          | 60° 16'         |
| 12. <i>Zinnwaldite</i> —                    | "       | "        | " " "                        | Zinnwald, Saxony         | 59° 12'         |
| 13. <i>Biotite</i> —                        | $\perp$ | "        | " " "                        | Arendal, Norway          | practically 60° |
| 14. " "                                     | "       | "        | " " "                        | Siberia                  | "               |
| 15. <i>Magnesiaglimmer</i> *<br>(Anomite ?) | "       | "        | " " "                        | Lake Baikal              |                 |
| 16. <i>Phlogopite</i> —                     | "       | "        | " " "                        | Radigara, Ceylon         | 60° 52'         |
| 17. " "                                     | "       | "        | " " "                        | South Burgess, Ont.      | 61° 53'         |
| 18. " "                                     | "       | "        | " " "                        | Radigara, Ceylon         | 62° 27'         |
| 19. " "                                     | "       | "        | " " "                        | Radigara, Ceylon         | 63° 28'         |

The above table shows that the angle  $\chi$  varies from 52° 53' in muscovite from Murray Bay, Canada, to 63° 28' in phlogopite from Radigara, Ceylon. It is noteworthy that all the micas examined, when arranged in a series according to the magnitude of the angle  $\chi$ , then all the muscovites are together in one group which is quite separated from all the other micas; then follow the lithia micas in a second group, the biotites in a third and finally the phlogopites. We notice, however, that in this respect, the lepidolites and zinnwaldites form only one group, though generally regarded as distinct species. Possibly such measurements as the above may be found useful in the determination and classification of micas. No measurements have been made of paragonite, lepidomelane or anomite. In these species it may be different to obtain figures on which satisfactory measurements could be made.

The figures were produced with a large blunt darning needle. The smooth back of a small book formed a satisfactory foundation. Frequently after producing the figures on a somewhat thick sheet of mica, one may obtain good material for measurements by separating a very thin film from the bottom of the plate.

The so-called pressure figures, which are caused in mica plates by application of gradual pressure, using a slightly

\* Too dark and brittle for observation.



rounded punch, are generally described as consisting of rays forming with one another angles of very nearly  $60^\circ$ , and at right angles to the rays of the above-mentioned percussion figures. In the asterism of Canadian phlogopites, the rays of this star-phenomenon are said to have the same direction as the rays of the pressure figures. It would be interesting to know whether the rays of the pressure figures do really meet at angles of  $60^\circ$  or whether they are at right angles to the rays of the percussion figures. That they cannot be both, is clear from the above observations. The angle  $\chi$  probably varies slightly with the temperature of the plate on which the figures are made.

Leipsic, Jan. 24th, 1896.

ART. III. — *The Seven Day Weather Period*; by  
H. HELM CLAYTON.

IN this Journal, vol. xlvii, March, 1894, data were presented by the writer to show the existence in the United States of six and seven day periods or rhythms in the weather which apparently resulted from, or caused, a certain regularity in the movements of high and low pressure areas across the country.

To enable the investigation to be extended into other countries and embrace as large a part of the world as possible, the trustees of the Elizabeth Thompson fund allowed a grant of 200 dollars. This admitted of obtaining the assistance of Mr. Arthur Sweetland in the reductions.

Mr. A. Lawrence Rotch freely allowed the use of the large amount of observational data in his possession collected from all parts of the world, and by permitting the investigation to proceed as a part of the work of the Blue Hill Meteorological Observatory he made the completed results possible.

For the purpose of this research three stations were selected in the arctic region, four in the United States, five in Europe, two in Asia, two in Oceanica near the equator, three in middle South America, one in Mauritius, and one in Australia.

The work embraced the investigation of a weather period of 7 days 6.43 hours, another of 6 days 3.95 hours, and a third of 5 days 10.8 hours. The methods and results were in each case similar, and it is deemed necessary to recite in detail only those obtained for the first period. Beginning with January, 1880, an ephemeris was constructed for the 15 years ending

with Jan. 6, 11·7 P. M., 1896, which may be taken as the epoch. For each of the selected stations, during the entire time covered by available observations, the number of barometric minima which occurred on each day of the seven day period was counted. The first day consisted of the first 24 hours following the dates of the ephemeris, the second day consisted of the succeeding 24 hours, and so on for the seven days, the final quarter day being omitted. The number of barometric minima occurring on each day was selected because it is generally recognized by meteorologists that rain, temperature changes, etc., cluster around the barometric minima, and any periodicity discoverable in these minima implies a periodicity in all the other weather changes. The number of barometric minima observed on each day of the period at each of the stations selected is given in Table I, in which the days of maximum frequency are shown by the heavy-faced type.

TABLE I.

| UNITED STATES.  | Lat.       | Long.       | Years.                     | Day of Period. |            |            |            |            |            |            |
|-----------------|------------|-------------|----------------------------|----------------|------------|------------|------------|------------|------------|------------|
|                 |            |             |                            | 1              | 2          | 3          | 4          | 5          | 6          | 7          |
| Roseburg,       | 43° 13' N. | 123° 20' W. | 1885-93                    | 97             | 98         | 82         | <b>100</b> | 98         | <b>100</b> | 98         |
| Cheyenne,       | 41 8       | 104 48      | 1885-93                    | 113            | 96         | 108        | <b>109</b> | 103        | 106        | <b>120</b> |
| Chicago,        | 41 52      | 83 38       | 1885-93                    | 87             | <b>127</b> | 89         | 96         | 106        | <b>123</b> | 96         |
| Blue Hill,      | 42 12      | 71 6        | 1884-93                    | 121            | 97         | <b>150</b> | 128        | 120        | 109        | <b>153</b> |
| EUROPE.         |            |             |                            |                |            |            |            |            |            |            |
| Perpignan,      | 42° 42' N. | 0° 33' E.   | 1880-90                    | <b>120</b>     | 120        | 117        | 107        | <b>117</b> | 97         | 99         |
| Lesina,         | 43 10      | 16 27       | 1883-91                    | 68             | <b>83</b>  | 64         | 69         | <b>72</b>  | 58         | <b>74</b>  |
| Bucharest,      | 44 25      | 26 46       | 1885-91                    | <b>78</b>      | 45         | 60         | <b>69</b>  | 62         | 55         | 48         |
| Christiania,    | 59 55      | 10 43       | 1888-92                    | <b>51</b>      | 41         | 44         | <b>59</b>  | 47         | <b>51</b>  | <b>43</b>  |
| St. Petersburg, | 59 56      | 30 16       | 1885-90                    | 57             | <b>59</b>  | 39         | 61         | <b>65</b>  | 57         | <b>67</b>  |
| ARCTIC REGION.  |            |             |                            |                |            |            |            |            |            |            |
| Point Barrow,   | 71° 27' N. | 156° 15' W. | 1881-83                    | 11             | 12         | 12         | 11         | <b>17</b>  | 10         | 13         |
| Fort Conger,    | 81 44      | 64 45       | 1881-83                    | <b>17</b>      | 11         | 8          | <b>18</b>  | 10         | 11         | <b>17</b>  |
| Ekholm,         | 78 28      | 15 40       | 1882-83                    | <b>10</b>      | 8          | <b>10</b>  | 4          | 9          | 7          | 5          |
| ASIA.           |            |             |                            |                |            |            |            |            |            |            |
| Zi Ka Wei,      | 31° 11' N. | 121° 23' E. | 1885-92                    | 41             | 49         | <b>57</b>  | 39         | 53         | 52         | <b>54</b>  |
| Tokio,          | 35 41      | 139 46      | { 1885-86 }<br>{ 1890-93 } | <b>75</b>      | 65         | 65         | <b>68</b>  | 67         | 58         | 66         |
| OCEANICA.       |            |             |                            |                |            |            |            |            |            |            |
| Manilla,        | 14° 35' N. | 120° 59' E. | 1890-91                    | <b>26</b>      | 21         | 21         | 21         | 17         | 19         | 19         |
| Batavia,        | 6 11 S.    | 106 50      | 1881-92                    | 91             | 110        | 76         | 107        | 100        | <b>106</b> | 99         |
| SOUTH AMERICA.  |            |             |                            |                |            |            |            |            |            |            |
| Matanzas,       | 34° 48' S. | 58° 37' W.  | 1880-89                    | 89             | 84         | <b>100</b> | 83         | 81         | 81         | <b>100</b> |
| Corrientes,     | 27 28      | 58 45       | 1881-89                    | 66             | 70         | <b>77</b>  | 75         | 66         | <b>68</b>  | 63         |
| Rio Janeiro,    | 22 20      | 43 55       | 1883-91                    | <b>54</b>      | 38         | <b>50</b>  | 44         | 48         | <b>51</b>  | 45         |
| AFRICA.         |            |             |                            |                |            |            |            |            |            |            |
| Mauritius,      | 20° 5' S.  | 57° 30' E.  | 1887-92                    | 31             | 33         | 39         | 39         | <b>40</b>  | 32         | 34         |
| AUSTRALIA.      |            |             |                            |                |            |            |            |            |            |            |
| Flagstaff,      | 37° 48' S. | 143° 45' E. | 1889-92                    | <b>39</b>      | 28         | <b>36</b>  | 33         | 28         | 27         | 35         |

The results show that in general there are two maxima and two minima of frequency during the seven days, and at some stations there appear to be three. If the positions of maximum frequency at each station are determined by constantly acting causes, it is to be expected that when the time covered by observations is divided into shorter intervals the maxima would tend to occur on the same days of the period provided the intervals are not too short. At all stations where the observations were available for a time long enough to permit it, they were separated into groups of three years, and the frequency of barometric minima was determined for each day of the seven day period in each group. Groups of ten years would have been better had the observations been for a long enough time to permit them. The results are given in Table II for a few stations scattered as widely as possible, the maxima being indicated as before by heavy-faced type.

TABLE II.

| Station.   | Years.         | Day of Period. |           |           |           |           |           |           |
|------------|----------------|----------------|-----------|-----------|-----------|-----------|-----------|-----------|
|            |                | 1              | 2         | 3         | 4         | 5         | 6         | 7         |
| Chicago,   | 1885-87        | 24             | <b>35</b> | 24        | 25        | 36        | <b>37</b> | 34        |
|            | 1888-90        | 25             | <b>46</b> | 29        | 38        | 28        | <b>43</b> | 28        |
|            | 1891-93        | 38             | <b>46</b> | 36        | 33        | 42        | <b>43</b> | 34        |
| Perpignan, | 1880-83        | <b>47</b>      | 46        | 45        | <b>49</b> | 46        | 29        | 40        |
|            | 1884-86        | <b>36</b>      | 27        | 32        | <b>35</b> | 31        | 29        | 20        |
|            | 1887-90        | 37             | <b>47</b> | 40        | 23        | <b>40</b> | 39        | 39        |
| Zi Ka Wei, | '85, '88, '89, | 21             | 31        | <b>37</b> | 23        | <b>38</b> | 27        | <b>28</b> |
|            | 1890, '92      | 20             | 18        | <b>20</b> | 16        | 15        | 25        | <b>26</b> |
| Batavia,   | 1881-83        | 16             | <b>25</b> | 22        | 21        | 23        | <b>30</b> | 23        |
|            | 1884-86        | 23             | <b>30</b> | 18        | 24        | 19        | <b>26</b> | 26        |
|            | 1887-89        | 27             | <b>27</b> | 14        | 29        | <b>30</b> | 20        | 23        |
|            | 1890-92        | 25             | <b>28</b> | 22        | <b>33</b> | 28        | <b>30</b> | 26        |
| Matanzas,  | 1880-83        | 34             | 34        | <b>38</b> | 34        | 30        | 34        | <b>49</b> |
|            | 1884-86        | 28             | <b>31</b> | 28        | 22        | <b>30</b> | 18        | 21        |
|            | 1887-89        | 27             | 19        | <b>34</b> | 27        | 21        | 29        | <b>30</b> |

These stations are those which have the longest series of available observations, and the results show that all over the world the days of the period on which the maximum frequency of barometric minima occurs at any station tend to remain the same at that station during succeeding years.

The results in Table I were plotted in curves and studied from two different standpoints:—

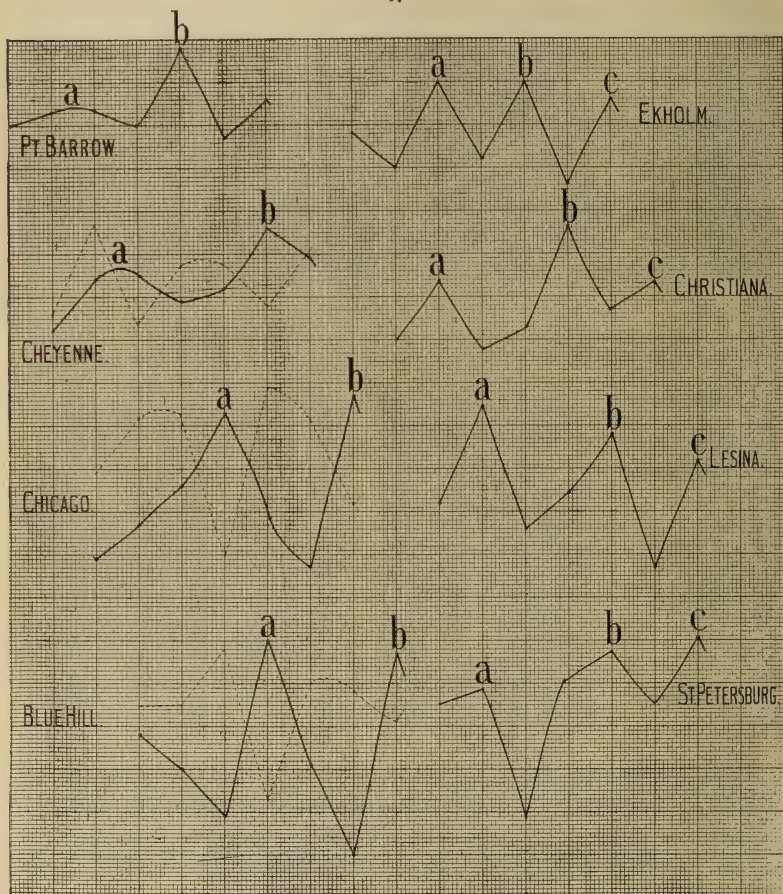
(1) Stations near the same latitude but differing in longitude were plotted under one another to see what relation existed between adjacent stations.

(2) Stations near the same longitude but differing in latitude were plotted under one another for the same purpose. The results for adjacent stations showed that the days of maximum



frequency occurred first at higher latitudes and at western stations, indicating that the periodicity was connected with barometric waves which swept from the poles toward the equator and from west to east, or in other words from the northwest.

1.



Beginning in the arctic region, the results for several successive stations lying in a general N.W. to S.E. direction are plotted in diagram 1 for both Europe and America. The beginnings of the curves are displaced one day for each successive difference of about  $15^{\circ}$  of longitude or latitude so as to show the corresponding points of the curves. The American stations are Pt. Barrow, Cheyenne, Chicago, and Blue Hill,

and the European stations Ekholm, Christiania, Lesina, and St. Petersburg. The curves seem to indicate very clearly in the average that twice in a period of 7 days 6.43 hours in America, and three times in Europe, waves of barometric minima, or storms, tend to begin near the poles and sweep across the continents.

The day of the period in which occurred the maximum  $b$ , shown in diagram 1, was plotted on a map for each station in Europe and America. The heavy lines in diagram 2 show the position of the maximum storm frequency for each suc-

2.



cessive day. It is seen that the first line in America passes through Pt. Barrow on the extreme northern coast; two days later it passes through Cheyenne in the central United States and two days later through Blue Hill on the Atlantic coast. In Europe it first passes through Ekholm near the arctic circle east of Greenland; a day later it passes through Christiania in southern Norway; a day later, through St. Petersburg in northern, and Lesina in southern Europe, and a day later over Bucharest near the Black Sea.

To determine whether these days of maximum storm frequency remained the same at each station throughout the year or changed with the seasons, the observations at each station were divided into four seasons, namely: December to February, March to May, June to August, and September to

November, and storm frequencies were determined for each day of the seven day period. The results for a few stations, separated as widely as possible, are given in Table III.

TABLE III.

|                     | Day of Period. |           |    |           |           |           |           |
|---------------------|----------------|-----------|----|-----------|-----------|-----------|-----------|
|                     | 1              | 2         | 3  | 4         | 5         | 6         | 7         |
| Chicago,            |                |           |    |           |           |           |           |
| December-February,  | 23             | <b>33</b> | 27 | 26        | 23        | <b>39</b> | 26        |
| March-May,          | 22             | <b>35</b> | 22 | 25        | <b>34</b> | 23        | 22        |
| June-August,        | 18             | 22        | 16 | 23        | 22        | <b>30</b> | 23        |
| September-November, | 24             | <b>37</b> | 24 | 27        | 27        | <b>31</b> | 25        |
| Bucharest,          | 7              | 1         | 2  | 3         | 4         | 5         | 6         |
| December-February,  | 13             | <b>18</b> | 12 | 8         | <b>20</b> | 13        | 16        |
| March-May,          | 10             | <b>23</b> | 9  | <b>20</b> | 17        | 18        | 15        |
| June-August,        | 12             | <b>20</b> | 10 | 16        | 15        | <b>18</b> | 12        |
| September-November, | 13             | <b>17</b> | 14 | 16        | <b>17</b> | 13        | 12        |
| Zi Ka Wei,          | 2              | 3         | 4  | 5         | 6         | 7         | 1         |
| December-February,  | 12             | <b>12</b> | 10 | 10        | <b>14</b> | 14        | 5         |
| March-May,          | 16             | <b>17</b> | 14 | 14        | 14        | <b>17</b> | 15        |
| June-August,        | 12             | <b>12</b> | 6  | <b>14</b> | 9         | 10        | 9         |
| September-November, | 9              | <b>16</b> | 9  | 15        | <b>15</b> | 5         | 12        |
| Batavia,            | 1              | 2         | 3  | 4         | 5         | 6         | 7         |
| December-February,  | 21             | <b>24</b> | 19 | <b>28</b> | 17        | 24        | <b>30</b> |
| March-May,          | 25             | <b>26</b> | 20 | 24        | 23        | <b>28</b> | 24        |
| June-August,        | 17             | <b>26</b> | 17 | 26        | <b>28</b> | 14        | 22        |
| September-November, | 28             | <b>34</b> | 20 | 29        | 32        | <b>40</b> | 22        |
| Matanzas,           | 2              | 3         | 4  | 5         | 6         | 7         | 1         |
| December-February,  | 17             | <b>23</b> | 22 | 16        | 16        | <b>26</b> | 26        |
| March-May,          | 19             | <b>27</b> | 24 | 22        | 23        | 23        | <b>24</b> |
| June-August,        | 25             | <b>27</b> | 15 | <b>23</b> | 22        | 20        | 20        |
| September-November, | 23             | <b>23</b> | 22 | 20        | 20        | <b>30</b> | 19        |
| Flagstaff,          | 7              | 1         | 2  | 3         | 4         | 5         | 6         |
| December-February,  | <b>9</b>       | 7         | 8  | 7         | <b>9</b>  | 6         | 9         |
| March-May,          | 7              | <b>10</b> | 8  | 7         | 8         | <b>9</b>  | 8         |
| June-August,        | 10             | <b>11</b> | 6  | 8         | <b>8</b>  | 7         | 1         |
| September-November, | 9              | <b>11</b> | 6  | <b>14</b> | 7         | 6         | 9         |

The data in the table are so arranged that what appear to be corresponding days at all the stations come under one another, the day of the period being given above the data for each station.

The heavy-faced figures showing the maxima render it apparent that there is a tendency at every station for the days of maximum frequency to remain on the same days of the period throughout the year. Thus at Chicago the maxima tend to occur on the second and between the fifth and sixth day of the period; at Bucharest they tend to occur on the first and between the fourth and fifth day of the period, etc.

If, however, the curves are plotted they show considerable irregularities and dissimilarities. Smoother and more com-



parable results are found by allowing for the drift of the barometric waves as previously found and adding several stations together. Thus the results for Cheyenne are added to those found one day later at Chicago and these to those found one day later at Blue Hill. In this way a larger number of observations is obtained and local influences are eliminated. In the same way, allowing one day between each station, the results for Lesina, Bucharest, and Perpignan, are added together. Those for Zi Ka Wei and Tokio and for Batavia and Manila are added with one day between, and those for Matanzas, Corrientes and Rio Janeiro are added together, allowing one day between the last and first two stations. The results are given in Table IV under the headings of United States, Europe, Asia, Oceanica and South America, and are shown in diagram 3.

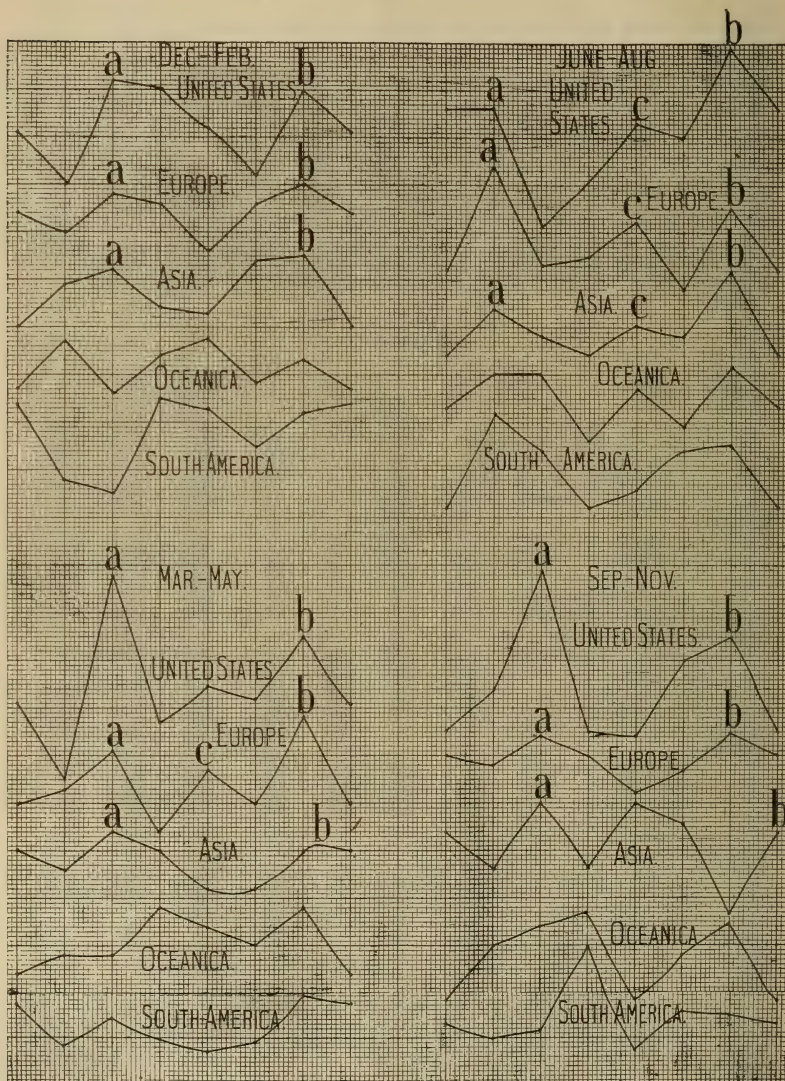
TABLE IV.

|                     | Day of Period. |            |           |           |            |           |           |
|---------------------|----------------|------------|-----------|-----------|------------|-----------|-----------|
|                     | 1              | 2          | 3         | 4         | 5          | 6         | 7         |
| United States,      |                |            |           |           |            |           |           |
| December-February,  | 82             | <b>100</b> | 91        | 80        | <b>102</b> | 100       | 92        |
| March-May,          | 82             | <b>95</b>  | 81        | 64        | <b>108</b> | 77        | 85*       |
| June-August,        | 70             | <b>89</b>  | <b>76</b> | <b>76</b> | 51         | 61        | 73*       |
| September-November, | 90             | <b>95</b>  | 75        | 84        | <b>109</b> | 75        | 74        |
| Europe.             |                |            |           |           |            |           |           |
| December-February,  | 61             | <b>64</b>  | 58        | 54        | <b>62</b>  | 60        | 50        |
| March-May,          | 60             | <b>78</b>  | 60        | 64        | <b>71</b>  | 54        | 67*       |
| June-August,        | 48             | <b>65</b>  | 52        | <b>74</b> | 53         | 54        | 62*       |
| September-November, | 57             | <b>65</b>  | 60        | 58        | <b>64</b>  | 60        | 52        |
| Asia.               |                |            |           |           |            |           |           |
| December-February,  | 34             | <b>35</b>  | 20        | 29        | <b>32</b>  | 24        | 23        |
| March-May,          | 31             | <b>35</b>  | 35        | 33        | <b>37</b>  | 35        | 31        |
| June-August,        | 22             | <b>29</b>  | 20        | <b>25</b> | 22         | 20        | 23*       |
| September-November, | 32             | 22         | 31        | 27        | <b>34</b>  | 27        | <b>34</b> |
| Oceanica.           |                |            |           |           |            |           |           |
| December-February,  | 24             | <b>29</b>  | 23        | <b>33</b> | 22         | 30        | <b>34</b> |
| March-May,          | 32             | <b>36</b>  | 29        | 31        | 31         | <b>36</b> | 34        |
| June-August,        | 19             | <b>32</b>  | 23        | <b>30</b> | 30         | 16        | 27*       |
| September-November, | 32             | <b>39</b>  | 22        | 34        | 38         | <b>41</b> | 22        |
| South America.      |                |            |           |           |            |           |           |
| December-February,  | 45             | 52         | <b>54</b> | 38        | 35         | <b>55</b> | 53        |
| March-May,          | 49             | <b>59</b>  | 57        | 48        | <b>54</b>  | 50        | 47        |
| June-August,        | 54             | <b>55</b>  | 42        | <b>62</b> | 34         | 42        | 46        |
| September-November, | 56             | <b>55</b>  | 53        | 50        | 51         | <b>70</b> | 47        |

The "Day of Period" at the top of Table IV has no further significance than for use in reference. The curves in diagram 3 begin on the third day of the table as arranged above. These curves, at least for the northern hemisphere, show a marked similarity for the same season in different countries. In winter there are two maxima of storm frequency, marked *a* and *b* in the diagram; in spring a slight

tertiary maximum marked *c* shows itself in Europe and the United States. This third maximum becomes general over the

3.



northern hemisphere in summer. In autumn the double maximum again becomes predominant. In Oceanica nearly under the equator there appears to be a tendency to three maxima in

the frequency of barometric minima except from September to November.

In South America only two maxima appear, but the positions of the maxima tend to vary simultaneously with those in the northern hemisphere, and thus add some support to the hypothesis that the causes of variation in the period are cosmical and not seasonal.

As a further investigation the number of barometric maxima occurring on each day of the period was counted for all the above mentioned stations in Europe and the United States. The results show, with only one or two slight exceptions, the greatest frequency of barometric maxima about half way between the barometric minima, and when the two are plotted together they show similar, but reversed, curves. Since this result is perhaps what was naturally to be expected, the tabular matter is omitted here, but the results for Cheyenne, Chicago, and Blue Hill are plotted in diagram 1 by means of dotted lines over the continuous curves which show the frequency of barometric minima.

To ascertain to what extent the period would show itself in short intervals, the periods were separated into groups of eleven periods occupying about eleven weeks each, and the barometer observations taken three times a day at Blue Hill Observatory were averaged for each eight hours of the period from 1890 to 1895. The results for 1890 were the most marked and are given below, though I think the results for each year sufficiently confirm the existence of the period. The dates in this table are the dates of the beginning of each group.

TABLE V.

| Day           | 1           | 2           | 3           | 4           | 5           | 6  | 7 |
|---------------|-------------|-------------|-------------|-------------|-------------|----|---|
| Bar. 29+ inch |             |             |             |             |             |    |   |
| Jan. 3 .....  | 35 42 45 49 | 52 49 43 33 | 29 24 27 31 | 31 29 28 33 | 32 27 18 20 | 26 |   |
| Mar. 16 ..... | 24 32 36 38 | 35 30 22 20 | 22 24 27 31 | 30 26 28 31 | 29 27 23 22 | 24 |   |
| June 4 .....  | 29 30 31 29 | 29 32 33 36 | 39 41 42 41 | 39 37 34 29 | 28 25 23 27 |    |   |
| Aug. 23 ..... | 27 29 32 34 | 31 28 38 41 | 42 41 29 28 | 31 32 31 26 | 20 17 16 19 | 22 |   |
| Oct. 6 .....  | 12 12 12 19 | 20 28 37 41 | 42 32 22 18 | 19 26 31 27 | 21 15 09 12 | 14 |   |

It will be seen from Table V that the chief minimum remained persistent on the seventh day. The secondary minimum moved forward from the beginning of the fourth day in winter to the end of the second day in the period in summer, and toward the end of summer showed a double minimum, one on the second, and the other on the fourth day. In autumn and early winter the minima are again on the fourth and the seventh



day. Hence the average lowest pressure, even for short intervals during 1890, occurred on exactly the same days of the period as the greatest frequency of barometric minima during the ten years' observation. The period was less marked during subsequent years and longer intervals are required to show the same persistency.

To determine the relation of the period to temperature changes at Blue Hill, the departures from the normal temperatures were determined for each day during 1887 and 1888 at 8 A. M. and 8 P. M. These were then arranged in seven day periods and averaged. The results in the following table show the departures from the mean or normal of the two years :

TABLE VI.

| Day  | 1        | 2        | 3        | 4        | 5        | 6        | 7        |
|------|----------|----------|----------|----------|----------|----------|----------|
| Dep. | -1.0-1.2 | -0.7+0.0 | +0.5+0.2 | -0.1-0.4 | -0.1+0.7 | +1.3+0.7 | -0.1-0.9 |

The results show the greatest plus departures on the third and the sixth day, or about one day preceding the lowest mean barometric pressures, with the extremes of the temperature and pressure departures on the sixth and the seventh day respectively. The greatest minus temperature departures are found on the first and the fourth day, with the lowest mean temperature on the first.

It must be evident to every one who accepts these investigations that a promising and important field is here presented for weather forecasting. As yet we are confined to averages in forecasting. An effort to follow and separate the individual periods has been attended with only a slight success.

It is possible to say that in all parts of the world barometric minima will be from 10 to 20 per cent more frequent on certain days than on certain other days, provided the interval taken is sufficiently long. It is also possible to say that certain days will average colder than other days. I think even this information would prove of value to certain industries, and I have an abiding faith that it is only the beginning of the science of weather forecasting which is yet to come.

## ART. IV.—On Pearceite, a Sulpharsenite of Silver and on the Crystallization of Polybasite; by S. L. PENFIELD.

## 1. Pearceite.

THE mineral to be described as pearceite in the present article is a sulpharsenite of silver,  $\text{Ag}_9\text{AsS}_6$  or  $9\text{Ag}_2\text{S}, \text{As}_2\text{S}_3$ , analogous to polybasite  $\text{Ag}_9\text{SbS}_6$ , and like the latter characterized by having a part of the silver replaced by copper and often by small quantities of zinc and iron. It can not be claimed to be a *new mineral*, for as an arsenical variety of polybasite it has previously been recognized although no special name has been assigned to it. H. Rose\* first described polybasite and gave the name to the species in 1828, and in 1833 he published† an analysis of a specimen from Schemnitz containing arsenic, with only a trace of antimony, while in the original polybasite from Durango, Mexico, described by him, both antimony and arsenic were present, and he recognized the fact that these elements were isomorphous and could mutually replace one another. The polybasites from Durango in Mexico, Freiberg in Saxony, Příbram in Bohemia, the Two Sisters' mine near Georgetown, the Yankee Boy mine near Ouray, and the Sheridan mine near Telluride in Colorado, the Comstock Lode in Nevada, and apparently from most localities, are essentially the antimony variety, and in mineralogical literature the composition of polybasite is usually given as a *sulphantimonite* of silver. Rammelsberg‡ gives an analysis by Joy of polybasite from Cornwall, England, where antimony and arsenic are present in about equal molecular proportions, and the author in connection with Mr. Stanley H. Pearce, has published§ analyses of arsenical polybasite (*pearceite*) from the Mollie Gibson mine, Aspen, Colorado. This latter material was not distinctly crystallized, but was found in great quantity and was the mineral which carried the bulk of the silver in the most productive silver mine in Colorado at that time.

The author's attention has recently been called to the occurrence of beautifully crystallized pearceite, or arsenical polybasite from the Drumlummon mine, Marysville, Lewis and Clarke Co., Montana. The mineral was first sent by Mr. R. F. Bayliss, of the Montana Mining Co., to Dr. Richard Pearce, of Denver, with the request that it should be investigated, and

\* Pogg. Ann., xv, p. 573, 1829.

† Loc. cit., xxviii, p. 56, 1833.

‡ Mineralchemie, p. 102, 1860.

§ This Journal, xlv, p. 15, 1892.

the following analysis was made by Mr. F. C. Knight under Dr. Pearce's immediate supervision.

|        | Found.        | Ratio. |           | Theoretical composition where<br>Ag <sub>2</sub> : Cu <sub>2</sub> : Fe = 255 : 143 : 19. |
|--------|---------------|--------|-----------|---|
| S      | 17.71 ÷ 32 =  | .553   | 11.95     | 17.96   |
| As     | 7.39 ÷ 75 =   | .098   | 2.11      | 7.02  |
| Ag     | 55.17 ÷ 216 = | .255   | .417 9.00 | 55.61   |
| Cu     | 18.11 ÷ 127 = | .143   |           | 18.34   |
| Fe     | 1.05 ÷ 56 =   | .019   |           | 1.07  |
| Insol. | .42           |        |           |   |
|        | <hr/> 99.85   |        |           | <hr/> 100.00  |

Dr. Pearce recognized that the mineral belonged to the polybasite class, where arsenic played the role usually taken by antimony, and forwarded the specimens, together with the analysis, to the author for an expression of opinion. As may be seen from the ratio, the proportion of S : As : (Ag<sub>2</sub> + Cu<sub>2</sub> + Fe) is very nearly 12 : 2 : 9, which is that demanded by the polybasite formula, and taking the metals in the same proportion as they are found in the analysis, Ag<sub>2</sub> : Cu<sub>2</sub> : Fe = 255 : 143 : 19, and calculating the theoretical composition, results agreeing very satisfactorily with the analysis are obtained.

Although recognizing that antimony and arsenic are isomorphous and may mutually replace one another, it is customary and has been found convenient in mineralogy to consider the sulphantimonites and sulpharsenites as distinct species, and to designate them by different names, and the author proposes that hereafter the name polybasite shall be restricted to the antimony compound Ag<sub>2</sub>SbS<sub>6</sub>, and to make of the corresponding arsenic compound Ag<sub>2</sub>AsS<sub>6</sub> a distinct species. For the arsenical mineral he takes pleasure in proposing the name *pearceite* as a compliment to his friend, Dr. Richard Pearce, of Denver, whose keen interest in mineralogy and connection with one of the large smelting and refining works of Colorado have made him known both to scientific men and to those interested in the development of the mining industries of the Rocky Mountain region. The author furthermore takes pleasure in expressing his thanks to Mr. Bayliss, who has taken a great interest in the investigation and naming of the mineral, and has most generously placed at his disposal all of the available material.

It seems best to give at this point the analyses of pearceite, already referred to, which have previously been published as arsenical varieties of polybasite. In the theoretical composition given with each the ratio of the metals is the same as in the accompanying analysis.



- I. H. Rose,  $\text{Ag}_2 : \text{Cu}_2 : \text{Zn} : \text{Fe} = 335 : 24 : 9 : 6$ .  
 II. Penfield, after deducting 12·81 per cent of impurities,  
 mostly  $\text{PbS}$ ,  $\text{Ag}_2 : \text{Cu}_2 : \text{Zn} = 263 : 117 : 43$ .  
 III. S. H. Pearce, after deducting 28·18 per cent of impurities,  
 mostly  $\text{PbS}$ ,  $\text{Ag}_2 : \text{Cu} : \text{Zn} = 276 : 102 : 49$ .

|    | I.<br>Schemnitz. Theory. |        | II.<br>Aspen, Colo. Theory. |        | III.<br>Aspen. Theory. |        | Theory for<br>$\text{Ag}_2\text{AsS}_6$ . |
|----|--------------------------|--------|-----------------------------|--------|------------------------|--------|---|
| S. | 16·83                    | 16·19  | 18·13                       | 18·13  | 17·73                  | 18·02  | 15·50                                     |
| As | 6·23                     | 6·32   | 7·01                        | 7·08   | 6·29                   | 7·03   | 6·05                                      |
| Sb | 0·25                     | ----   | ·30                         | ----   | 0·18                   | ----   | ----                                      |
| Ag | 72·43                    | 73·47  | 56·90                       | 57·07  | 59·73                  | 59·06  | 78·45                                     |
| Cu | 3·04                     | 3·08   | 14·85                       | 14·91  | 12·91                  | 12·77  | ----                                      |
| Zn | 0·59                     | 0·60   | 2·81                        | 2·81   | 3·16                   | 3·12   | ----                                      |
| Fe | 0·33                     | 0·34   | ----                        | ----   | ----                   | ----   | ----                                      |
|    | 99·70                    | 100·00 | 100·00                      | 100·00 | 100·00                 | 100·00 | 100·00                                    |

### Crystallization.

The crystallization of pearceite is *monoclinic* but with a close approximation to rhombohedral symmetry. The habit is commonly hexagonal with the basal planes prominent and the zones of bevelling forms between them often highly modified. The material from which crystallographic data could be obtained came wholly from a single specimen where the crystals were implanted upon a gangue of quartz and imbedded in calcite, and were obtained by dissolving the latter in dilute acid. Unfortunately the crystals had grown close together, thus interfering more or less with one another, and they also were cracked, probably owing to the severe shocks received in the processes of blasting and mining; consequently when liberated by dissolving the calcite they fell to pieces, so that usually only parts of crystals were available for measurement. The faces had a beautiful metallic luster, and when free from striations and vicinal planes gave excellent reflections on the goniometer. The determination of the crystalline form and the axial ratio proved to be a difficult matter owing to the fragmentary character of the crystals, their grouping, often in nearly parallel position, a probable twinning and their close approximation to rhombohedral symmetry, and it was not until many measurements had been made upon a series of crystals that a satisfactory solution of the problem was obtained.

As fundamental measurements, the following were selected :

$$\begin{aligned}
 m \wedge m, 110 \wedge \bar{1}10 &= 60^\circ \quad 2' \\
 c \wedge d, 001 \wedge 102 &= 25 \quad 3 \\
 c \wedge a, 001 \wedge 100 &= 89 \quad 51
 \end{aligned}$$

from which the axial ratio was calculated :

$$a : b : c = 1.7309 : 1 : 1.6199$$

$$\beta = 001 \wedge 100 = 89^\circ 51'.$$

The crystals are quite highly modified, and it seems best before giving a list of the forms to explain the different kinds which were observed and to state something concerning their occurrence. The basal pinacoid  $c, 001$  is prominent, is hexagonal or triangular in shape, and is characterized by triangular markings and vicinal planes, fig. 1, so that it was often impossible to obtain accurate measurements from it. The prism  $m, 110$  and the pinacoid  $a, 100$  are nearly at right angles to  $c$  and  $60^\circ$  from one another, so that the combination approaches very closely to an hexagonal prism, and it is sometimes impossible to distinguish  $a$  from  $m$ , or without accurate measurements to decide whether the forms between  $c$  and  $a$  or  $c$  and  $m$  modify the acute or obtuse angles. It is very probable that a twinning is present, similar to that of the micas and chlorites, where the twinning plane is at right angles to  $c$  in the zone  $m \wedge c$  and where the parts are superimposed upon one another with  $c$  as the composition face, but no absolute proof of this was obtained. The crystals are opaque, so that optical tests could not be applied as was done by Miers,\* who has described this kind of twinning on polybasite. If the twinning occurs on pearceite, as it probably does, it must cause uncertainty as to the identification of some of the forms in the zones between  $c$  and  $a$  and  $c$  and  $m$ , and it may also account in part for the decidedly rhombohedral aspect of many of the crystals. As far as could be observed, similar faces are often developed about equally above and below  $m$  and  $a$  in the zones between the basal planes, but to what extent this is due to twinning it is impossible to state. The faces in these zones are moreover commonly striated parallel to their mutual intersection, and while  $r$  and  $p, r^\circ$  and  $p^\circ, n$  and  $t$  and  $n^\circ$  and  $t^\circ$  (compare fig. 1 and the list of forms beyond), are the most prominent, other faces, especially  $e$  and  $e^\circ, f$  and  $f^\circ, s$  and  $s^\circ$  and  $u$  and  $u^\circ$ , are very often present. When  $g$  was observed it was always a prominent, dull face, not sharing in the horizontal striations of the other faces of the zone. It was only occasionally that forms were observed between  $c, 001$  and  $l, 310$ , and they were always small, while the corresponding forms were not observed between  $001$  and  $\bar{3}10$ . The pinacoid  $b, 010$  was identified, not only by the symmetrical arrangement of the forms with reference to it, but also by the similarity of the angles measured

\* Min. Mag., viii, p. 204, 1889.

from it on to similar adjacent forms. The prism  $l$ , 310 is often developed about equal in size to  $b$ , and with the latter would correspond in rhombohedral symmetry to a hexagonal prism of the second order. The prism  $h$ , 130 and the horizontal prism  $k$ , 021 were found together on only one crystal as small faces symmetrically located with reference to the pinacoid  $b$ .

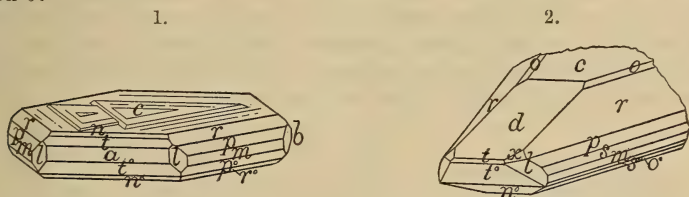


Fig. 1 shows the prevailing type of crystal, with hexagonal aspect, the characteristic triangular markings on the basal plane, but with only the most prominent of the bevelling faces present. Two fragments were found which in habit were essentially like fig. 2. These had a decidedly monoclinic habit and were the most free from striations, vicinal faces and indications of a possible twinning of any crystals that were observed, and from them the fundamental measurements previously given were obtained.

A few crystals were quite remarkable for their size, the hexagonal plates being 3<sup>cm</sup> in diameter and 1<sup>cm</sup> thick, but they were coated with drusy quartz and could not be used for crystallographic measurement. The specimen showing the largest crystals was presented by Mr. Bayliss to the author for the Brush collection at New Haven. The crystals from which the measurements were obtained averaged less than 4<sup>mm</sup> in diameter.

The following list includes the forms which have been observed, but, as already stated, twinning may account for a similar form being found modifying both the acute and obtuse angles of the crystals and being repeated in the zones between  $c$  and  $a$  and  $c$  and  $m$ .

|           |                         |                         |                         |                         |
|-----------|-------------------------|-------------------------|-------------------------|-------------------------|
| $a$ , 100 | $d$ , 102               | $t^\circ$ , $\bar{2}01$ | $s$ , 221               | $s^\circ$ , $\bar{2}21$ |
| $b$ , 010 | $n$ , 101               | $e^\circ$ , 401         | $u$ , 331               | $u^\circ$ , $\bar{3}31$ |
| $c$ , 001 | $t$ , 201               | $f^\circ$ , $\bar{6}01$ | $o^\circ$ , $\bar{1}14$ | $x$ , 311               |
| $l$ , 310 | $e$ , 401               | $o$ , 114               | $q^\circ$ , $\bar{1}13$ | $y$ , 313               |
| $m$ , 110 | $f$ , 601               | $r$ , 112               | $r^\circ$ , $\bar{1}12$ | $z$ , $31\cdot12$       |
| $h$ , 130 | $\Delta$ , $\bar{2}03$  | $p$ , 111               | $p^\circ$ , $\bar{1}11$ |                         |
| $k$ , 021 | $n^\circ$ , $\bar{1}01$ | $v$ , 332               | $v^\circ$ , $\bar{3}32$ |                         |

The forms corresponding to these found by Miers\* on polybasite are  $c$ ,  $m$ ,  $n$ ,  $t$ ,  $p$ ,  $s$ ,  $r$  and  $w$ , 109.

\* Loc. cit.



The following table of measured angles includes a series which was selected wholly on account of the character of the reflections, due to the freedom of the faces from striations and other disturbing influences. They were mostly made on the two fragmentary crystals, already mentioned, having a habit like fig. 2, and where several measurements are given they represent independent ones in different zones or on different crystals. As may be seen, the measured angles show a fairly good agreement with the calculated values, and it may, therefore, be assumed that the axial ratio has been determined with a fair degree of accuracy.

|  | Calculated,         | Measured.   |  |
|--|---------------------|---|--|
| $c \wedge a, 001 \wedge 100$             | $89^\circ 51'$      | $89^\circ 51'^*$ , $89^\circ 49'$                                   |  |
| $c \wedge l, 001 \wedge 310$             | $89 52$             | $89 48,$ $89 54$  |  |
| $c \wedge m, 001 \wedge 110$             | $89 55\frac{1}{2}$  | $89 55$   |  |
| $m \wedge m, 110 \wedge \bar{1}10$       | $60 2$              | $60 2^*$  |  |
| $b \wedge m, 010 \wedge 110$             | $30 1$              | $30 1,$ $30 1$  |  |
| $a \wedge l, 100 \wedge 310$             | $29 59$             | $29 58,$ $29 57\frac{1}{4}$   |  |
| $b \wedge h, 010 \wedge 130$             | $10 54$             | $10 53$   |  |
| $b \wedge k, 010 \wedge 021$             | $17 9$              | $17 5$  |  |
| $c \wedge d, 001 \wedge 102$             | $25 3$              | $25 3^*,$ $25 2\frac{1}{2}$   |  |
| $c \wedge n, 001 \wedge 101$             | $43 2$              | $43 4,$ $43 5$  |  |
| $c \wedge e^\circ, 001 \wedge 40\bar{1}$ | $104 49$            | $104 53\frac{1}{2}$   |  |
| $c \wedge t^\circ, 001 \wedge 20\bar{1}$ | $118 00$            | $117 56$  |  |
| $c \wedge n^\circ, 001 \wedge 10\bar{1}$ | $136 49\frac{1}{2}$ | $136 52\frac{1}{2}$   |  |
| $c \wedge r, 001 \wedge 112$             | $43 3$              | $43 3,$ $\left. \begin{array}{l} 43 6 \\ 43 0 \end{array} \right\}$ |  |
| $c \wedge p, 001 \wedge 111$             | $61 49$             | $61 56$   |  |
| $d \wedge r, 102 \wedge 112$             | $36 14$             | $36 12,$ $36 16$  |  |
| $b \wedge p, 010 \wedge 111$             | $40 15$             | $40 12,$ $40 12$  |  |
| $b \wedge p^\circ, 010 \wedge \bar{1}11$ | $40 10\frac{1}{2}$  | $40 8$  |  |
| $b \wedge s, 010 \wedge 221$             | $33 12$             | $33 12$   |  |
| $c \wedge y, 001 \wedge 313$             | $47 9$              | $47 10,$ $47 7$   |  |

In the following table the calculated angles of most of the faces on to the basal plane are given, arranged so as to show the slight variation from one another and from rhombohedral symmetry of the forms  $d, o$  and  $o^\circ$ ;  $\Delta$  and  $q^\circ$ ;  $n, r, n^\circ$  and  $r^\circ$ ;  $t, p, t^\circ$  and  $p^\circ$ ;  $v$  and  $v^\circ$ ;  $e, s, e^\circ$  and  $s^\circ$  and  $f, u, f^\circ$  and  $u^\circ$ .

|                                      |  |                             |                                      |
|--------------------------------------|--|-----------------------------|--------------------------------------|
| $c \wedge d = 25^\circ 3'$           | $c \wedge n^\circ = 43^\circ 10\frac{1}{2}'$ | $c \wedge v = 70^\circ 19'$ | $c \wedge f = 79^\circ 45'$          |
| $c \wedge o = 25 3$                  | $c \wedge r^\circ = 43 7\frac{1}{2}$         | $c \wedge v^\circ = 70 27$  | $c \wedge u = 79 49\frac{1}{2}$      |
| $c \wedge o^\circ = 25 4\frac{1}{2}$ | $c \wedge t = 61 46\frac{1}{2}$              | $c \wedge e = 74 54$        | $c \wedge f^\circ = 80 2$            |
| $c \wedge \Delta = 32 0$             | $c \wedge p = 61 49$                         | $c \wedge s = 75 00$        | $c \wedge u^\circ = 79 58$           |
| $c \wedge q^\circ = 31 58$           | $c \wedge t^\circ = 62 00$                   | $c \wedge e^\circ = 75 11$  | $c \wedge z^\circ = 15 6\frac{1}{2}$ |
| $c \wedge n = 43 2$                  | $c \wedge p^\circ = 61 56$                   | $c \wedge s^\circ = 75 6$   | $c \wedge y = 47 9$                  |
| $c \wedge r = 43 3$                  |  |                             | $c \wedge x = 72 44$                 |

*Physical properties.*—Pearceite is brittle, has an irregular to conchoidal fracture and no distinct cleavage. The hardness

is about 3. The specific gravity was taken with a chemical balance on three different portions of carefully selected material and gave 6.125, 6.160 and 6.166, the mean of these being 6.15. The luster is metallic and the color of the mineral and the streak is black. The material, even in thin particles, is opaque. In the ruby silvers the arsenical compound proustite is more transparent than the antimony one pyrargyrite, and we might, therefore, naturally expect pearceite to be more transparent than polybasite, but that this is not the case may be due to the fact that the variety of pearceite under examination contains over 18 per cent of copper, while the published analyses of polybasite indicate usually about 5 and never over 10 per cent of this element.

*Pyrognostics and other tests.*—Before the blowpipe, pearceite decrepitates slightly and fuses at about one. Heated on charcoal in the oxidizing flame, a slight coating of  $\text{As}_2\text{O}_3$  is formed and by addition of borax or sodium carbonate and continued heating a globule of metallic silver is obtained. In the open tube  $\text{SO}_2$  is given off and a volatile sublimate of  $\text{As}_2\text{O}_3$  is formed. In the closed tube the mineral fuses, yields a yellow sublimate of sulphide of arsenic and above the latter a very slight one of sulphur. The powder is readily oxidized and dissolved by nitric acid, the solution yields with hydrochloric acid an abundant precipitate of silver chloride and on addition of ammonia in excess the blue color characteristic of copper is obtained, while a slight precipitate of ferric hydroxide is formed.

*Occurrence.*—According to information received from Mr. Bayliss, the pearceite crystals were found with quartz and calcite lining a vug at only one place in the Drumlummon mine, and although a diligent search has been made for similar crystals in other parts of the mine none have been found. A few chalcopyrite crystals were observed intimately associated with the pearceite. High grade silver and gold ores are taken from the Drumlummon mine, and on one of the specimens of the ore argentiferous tetrahedrite, freibergite, was observed.

## 2. *The Crystallization of Polybasite.*

Rose originally described polybasite as rhombohedral and it was thus considered until 1867, when Des Cloiseaux\* observed that the transparent plates showed in convergent polarized light a biaxial and not a uniaxial interference figure and that the mineral, therefore, could not be rhombohedral. The crystals were then referred to the orthorhombic system, but the close approximation to rhombohedral symmetry has always

\* *Nouvelles Recherches*, p. 85, 1867.

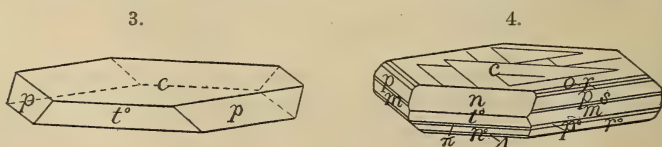
been prominently noted in descriptions of the mineral. The earlier measurements of polybasite crystals by Breithaupt\* are untrustworthy, probably owing to the difficulty of securing suitable material, and we are indebted to Miers† for the first careful series of measurements, which were made upon a suite of crystals in the British Museum. He also evidently experienced some difficulty in obtaining reliable measurements, for the angles between similar faces show a considerable variation amounting usually from a quarter to one-half of a degree. The crystals are regarded by him as orthorhombic and the following forms were observed :

|           |           |           |           |
|-----------|-----------|-----------|-----------|
| $c$ , 001 | $w$ , 109 | $t$ , 201 | $p$ , 111 |
| $m$ , 110 | $n$ , 101 | $r$ , 112 | $s$ , 221 |

Prominent angles are  $m : m$ ,  $110 \wedge \bar{1}10 = 60^\circ 10'$ ;  $c \wedge n$ ,  $001 \wedge 101 = 42^\circ 24'$  and  $c \wedge p$ ,  $001 \wedge 111 = 61^\circ 14'$ , the axial ratio being  $a : b : c = 1.7262 : 1 : 1.634$ . He also observed that the crystals when examined in polarized light did not become dark in any position and concluded, therefore, that they were twinned, as already explained on page 20 for pearceite. He points out the impossibility of distinguishing the bevelling faces  $r$  and  $p$  in the zone between  $c$  and  $m$  from  $n$  and  $t$  in the zone between  $c$  and  $a$ , and calls attention to the fact that the only form in these zones at right angles to the base is the prism  $m$  and that the pinacoid  $a$ , 100 fails. When six faces occur in the zone of the prisms the ones which occupy the positions of the pinacoid  $a$  are the prismatic faces  $m$  in twin position.

Dana‡ accepts the measurements of Miers as fundamental but shifts the position of the crystal so that the obtuse angle of the prism,  $m \wedge m$ , is in front.

Among the specimens in the Brush collection at New Haven one was found from the Himmelfahrt mine, Freiberg in Saxony, showing crystals like fig. 3, which is *apparently* a combination of base and rhombohedron. On revolving the crystals in polarized light they never became dark, showing thus that



a twinning was present, while in convergent light a confused interference figure was usually obtained, although in places the

\* Charakteristik des Mineral-Systems, 1832, p. 266.

† Min. Mag., viii, p. 204, 1889.

‡ System of Mineralogy, 6th edition, p. 146.



normal biaxial one was seen. There is nothing in the external aspect of the crystal to indicate twinning except perhaps the uneven character of the base  $c$ , which may result from a twinning about  $m$ , 110 and a slight deviation from  $90^\circ$  of  $c \wedge m$ . The crystal did not give satisfactory reflections, but the angle of  $c$  on the apparent rhombohedrons was approximately  $61\frac{1}{2}^\circ$  and of the latter faces on to each other  $80\frac{1}{2}^\circ$ . It is difficult to explain this apparently rhombohedral development on the assumption that the crystallization is orthorhombic, while it is known that monoclinic minerals whose prismatic angles are near  $60^\circ$ , the micas, chlorites and leadhillite for example, exhibit in a marked degree a tendency to imitate rhombohedral symmetry, while orthorhombic compounds, chalcocite, aragonite and witherite for example, do not show this tendency. It seems reasonable, therefore, to assume that the crystallization of polybasite, like that of pearceite, is *monoclinic*, and the apparently rhombohedral forms on fig. 3 have accordingly been lettered  $p$  and  $t^\circ$  with the understanding that there is an uncertainty regarding their identification.

In the summer of 1891, while the author was engaged in some mineralogical work in Colorado for the United States Geological Survey, a collection of minerals was made at the Yankee Boy mine, near Ouray, and thanks are due to Dr. F. M. Endlich, manager of the mine, for his courtesy and the interest which he took in making the collection as complete as possible. On the specimens, associated with pyrrargyrite and implanted upon quartz, were some small but remarkably perfect crystals of polybasite. The occurrence of the mineral from this locality has been noted by Endlich,\* the identification being based in part upon measurements by the author of the prismatic angle  $m \wedge m =$  nearly  $60^\circ$ .

The forms which were observed on a single crystal of polybasite, having a habit like fig. 4, are as follows, the orientation being derived from the symmetrical arrangement of the faces with reference to the prism  $l$ , 310, which, however, was only slightly developed and is not represented in the figure.

|           |                         |           |                         |
|-----------|-------------------------|-----------|-------------------------|
| $c$ , 001 | $\Delta$ , $\bar{2}03$  | $o$ , 114 | $u$ , 331 ?             |
| $l$ , 310 | $n^\circ$ , $\bar{1}01$ | $r$ , 112 | $o^\circ$ , $\bar{1}14$ |
| $m$ , 110 | $\pi$ , $\bar{4}03$     | $p$ , 111 | $r^\circ$ , $\bar{1}12$ |
| $n$ , 101 | $t^\circ$ , $\bar{2}01$ | $s$ , 221 | $p^\circ$ , $\bar{1}11$ |

The crystal was too opaque to admit of optical tests being made, but thinner crystals from the locality transmitted a deep red light and showed indications of twinning.

\* This Journal, xl, p. 424, 1890.

The following angles were taken as fundamental :

$$c \wedge m, 001 \wedge 110 = 90^\circ 0'$$

$$m \wedge m, 110 \wedge \bar{1}10 = 60 \quad 2$$

$$c \wedge n, 001 \wedge 101 = 42 \quad 23$$

from which the axial ratio was calculated

$$a : b : c = 1.7309 : 1 : 1.5796$$

$$\beta = 90^\circ 0'$$

The following table gives a record of the measurements which were made mostly on one crystal. The ones in brackets represent approximate measurements from very narrow faces.

|  | Calculated.              | Measured.        |                | Limits obtained<br>by Miers.       |
|--|--------------------------|------------------|----------------|------------------------------------|
| $c \wedge m, 001 \wedge 110$                         | $90^\circ 0'$            | $90^\circ 0'^*$  | $90^\circ 4$   |                                    |
| $c \wedge l, 001 \wedge 310$                         | $90 \quad 0$             | $90 \quad 0$     | $90 \quad 2'$  |                                    |
| $m \wedge m, 110 \wedge \bar{1}10$                   | $60 \quad 2$             | $60 \quad 2^*$   | $60 \quad 0$   | $60^\circ 10' -$                   |
| $c \wedge n, 001 \wedge 101$                         | $42 \quad 23$            | $42 \quad 23^*$  | $42 \quad 23$  | $40 \quad 48 - 42^\circ \quad 30'$ |
| $c \wedge \Delta, 001 \wedge \bar{2}03$              | $31 \quad 19$            | $31 \quad 22$    |                |                                    |
| $c \wedge n^\circ, 001 \wedge \bar{1}01$             | $42 \quad 23$            | $42 \quad 23$    |                |                                    |
| $c \wedge \pi, 001 \wedge \bar{4}03$                 | $50 \quad 35$            | $50 \quad 44$    |                |                                    |
| $c \wedge t^\circ, 001 \wedge \bar{2}01$             | $61 \quad 17$            | $61 \quad 25$    |                | $61 \quad 8 - 61 \quad 17$         |
| $c \wedge o, 001 \wedge 114$                         | $24 \quad 31$            | $(24 \quad 43)$  |                |                                    |
| $c \wedge r, 001 \wedge 112$                         | $42 \quad 22$            | $(42 \quad 43)$  | $(42 \quad 9)$ | $40 \quad 48 - 42 \quad 30$        |
| $c \wedge p, 001 \wedge 111$                         | $61 \quad 16$            | $61 \quad 15$    | $(61 \quad 7)$ | $61 \quad 5 - 61 \quad 24$         |
| $c \wedge s, 001 \wedge 221$                         | $74 \quad 40$            | $(74 \quad 48)$  |                | $73 \quad 55 - 75 \quad 50$        |
| $c \wedge u, 001 \wedge 331$                         | $79 \quad 39$            | $(78 \quad 2) ?$ |                |                                    |
| $c \wedge o^\circ, 001 \wedge \bar{1}14$             | $24 \quad 31$            | $(24 \quad 36)$  |                |                                    |
| $c \wedge r^\circ, 001 \wedge \bar{1}12$             | $42 \quad 22$            | $42 \quad 24$    |                |                                    |
| $c \wedge p^\circ, 001 \wedge \bar{1}11$             | $61 \quad 16$            | $(60 \quad 35)$  |                |                                    |
| $l \wedge p, 310 \wedge 111$                         | $40 \quad 35\frac{1}{2}$ | $40 \quad 36$    |                |                                    |
| $p \wedge r^\circ, 111 \wedge \bar{1}12$             | $49 \quad 26$            | $49 \quad 27$    |                |                                    |
| $r^\circ \wedge t^\circ, \bar{1}12 \wedge \bar{2}01$ | $49 \quad 24\frac{1}{2}$ | $49 \quad 38$    |                |                                    |
| $t^\circ \wedge l, \bar{2}01 \wedge \bar{3}\bar{1}0$ | $40 \quad 34$            | $40 \quad 34$    |                |                                    |

Certainly, as shown by the above table, the agreement between the measured and calculated values is very satisfactory, and it may be assumed, therefore, that the axial ratio has been determined with a fair degree of accuracy. That the crystallization is really monoclinic is shown by the development and arrangement of the faces, but the angle  $\beta$  differs so little from  $90^\circ$  that the variation, if any, falls within the errors of observation. Of four measurements that were made of  $c \wedge l$ , the faces being free from striations and giving excellent reflections, two were  $90^\circ 0'$  and the others  $90^\circ 2'$ . Six independent measurements of  $c \wedge m$  were made varying between  $90^\circ 0'$  and  $90^\circ 6'$ , but the  $m$  faces were slightly striated so that the measurements are not quite so reliable as those of  $c \wedge l$ .

*Relations of pearceite and polybasite to each other and to other minerals.*—Pearceite and polybasite show, as would be

expected, a very close relation to one another in everything which concerns their crystallization. The tendency of arsenic is to make the vertical axis of its compound a little longer than that of the antimony one, as shown by the following ratios and by the angles  $c \wedge p$  or  $p^\circ$ :

|             | $a : b : c$         | $\beta$ | $c \wedge p$ and $p^\circ$ |
|-------------|---------------------|---------|----------------------------|
| Pearceite,  | 1.7309 : 1 : 1.6199 | 89° 51' | 61° 49' 61° 56'            |
| Polybasite, | 1.7309 : 1 : 1.5796 | 90° 0'  | 61 16                      |

Perhaps the next most interesting relation of these minerals, which imitate rhombohedral symmetry, is their very close similarity to the rhombohedral ruby silvers, proustite  $\text{Ag}_3\text{As}_3\text{S}_3$ , and pyrrargyrite  $\text{Ag}_3\text{Sb}_3\text{S}_3$ , as shown by the relations of the vertical axis and the angles.

|             | $\frac{1}{2}c$          | $c \wedge p$ or $p^\circ$ |               | $\frac{1}{2}c$ | $c \wedge s$ |
|-------------|-------------------------|---------------------------|---------------|----------------|--------------|
| Pearceite,  | $\frac{1}{2}c = 0.8099$ | 61° 49'–61° 56'           | Proustite,    | $c = 0.8039$   | 61° 41½'     |
| Polybasite, | $\frac{1}{2}c = 0.7898$ | 61 16 –                   | Pyrrargyrite, | $c = 0.7891$   | 61 15        |

Difference = .0201

Difference = .0148

The vertical axes are longer in the arsenic than in the antimony compounds and to about the same extent in the two classes. In proustite and pyrrargyrite  $s$  is the  $-2$  rhombohedron,  $02\bar{2}1$ .

The orthorhombic sulphides, chalcocite  $\text{Cu}_2\text{S}$  and stromeyerite  $\text{CuAgS}$ , also exhibit a close and striking similarity to the minerals in question, best seen when the positions of the former are changed by a simple interchange of the  $a$  and  $b$  axes, making thus the obtuse angles of the prisms at the extremities of the  $b$  instead of the  $a$  axis, as follows:

|               | $a : b : c$         | $\beta$ | $m \wedge m,$<br>110 $\wedge$ $\bar{1}10$ | $c \wedge p$ or $p^\circ$ |
|---------------|---------------------|---------|---|---------------------------|
| Chalcocite,   | 1.7176 : 1 : 1.6663 | 90° 0'  | 60° 25'                                   | 62° 35½'                  |
| Stromeyerite, | 1.7176 : 1 : 1.6603 | 90 0    | 60 25                                     | 62 30                     |
| Pearceite,    | 1.7309 : 1 : 1.6199 | 89 51   | 60 2                                      | 61 49–61° 56'             |
| Polybasite,   | 1.7309 : 1 : 1.5796 | 90 0    | 60 2                                      | 61 16                     |

Although widely separated in our chemical classification, the differences in chemical composition of the two former from the two latter is not so very great, for Cu and Ag being isomorphous we have as the general composition of the former  $\text{R}'_2\text{S}$  and of the latter  $\text{R}'_2\text{S} + \frac{1}{3}\text{As}_2\text{S}_3$  respectively  $\text{Sb}_2\text{S}_3$ .

On examining the whole group of sulpharsenites and sulphantimonites it is quite interesting to note that the majority of them which are well crystallized exhibit prismatic angles of nearly 60° and show forms in other zones which can be referred to vertical axes nearly like those of the chalcocite and polybasite groups. These relations are shown in the following table, where the compounds are arranged according to varia-



tions in basity. The axes and angles have been taken from the sixth edition of Dana's Mineralogy, with the exception of those of xanthoconite and pyrostilpnite, which are taken from Miers,\* and of jordanite, taken from Baumhauer.\*\*

| Name.          | Composition.   | Syst. | $a : b : c$       | $\beta$        | $m \wedge m'$ | $c \wedge p$ or<br>equiv-<br>alent. | Change<br>of axes<br>from<br>Dana's<br>position. |
|----------------|--|-------|-------------------|----------------|---------------|-------------------------------------|--|
| Chalcocite     | $\text{Cu}_2\text{S}$  | O     | 1.718 : 1 : 1.666 |                | 60° 25'       | 62° 35'                             | $a=b$  |
| Pearceite      | $9\text{Ag}_2\text{S} \cdot \text{As}_2\text{S}_3$               | M     | 1.731 : 1 : 1.620 | 89° 51'        | 60 2          | 61 49                               |  |
| Polybasite     | $9\text{Ag}_2\text{S} \cdot \text{Sb}_2\text{S}_3$               | M     | 1.731 : 1 : 1.580 | 90 00          | 60 2          | 61 16                               |  |
| Stephanite     | $5\text{Ag}_2\text{S} \cdot \text{Sb}_2\text{S}_3$               | O     | 1.589 : 1 : 1.633 |                | 64 21         | 62 37                               | $a=b \cdot \frac{3}{2}c$                         |
| Geocronite     | $5\text{PbS} \cdot \text{Sb}_2\text{S}_3$                        | O     | 1.723 : 1 : 1.732 |                | 60 16         |                                     | $a=b \cdot 2c$                                   |
| Jordanite      | $4\text{PbS} \cdot \text{As}_2\text{S}_3$                        | M     | 1.862 : 1 : 1.883 | 90 33†         | 56 30         | 65 01                               | $b=c \cdot \frac{1}{2}c$                         |
| Meneghinite    | $4\text{PbS} \cdot \text{Sb}_2\text{S}_3$                        | O     | 1.891 : 1 : 1.831 |                | 55 45         |                                     | $a=b \cdot 2\frac{2}{3}c$                        |
| Proustite      | $3\text{Ag}_2\text{S} \cdot \text{As}_2\text{S}_3$               | R     | 1.732 : 1 : 1.608 |                | 60 0          | 61 41‡                              | $2c$   |
| Pyrrargyrite   | $3\text{Ag}_2\text{S} \cdot \text{Sb}_2\text{S}_3$               | R     | 1.732 : 1 : 1.578 |                | 60 0          | 61 15                               | $2c$   |
| Xanthoconite   | $3\text{Ag}_2\text{S} \cdot \text{As}_2\text{S}_3$               | M     | 1.919 : 1 : 1.523 | 88 47          | 55 4          |                                     | $\frac{3}{2}c$                                   |
| Pyrostilpnite  | $3\text{Ag}_2\text{S} \cdot \text{Sb}_2\text{S}_3$               | M     | 1.946 : 1 : 1.646 | 90 00          | 53 21         |                                     | $\frac{3}{2}c$                                   |
| Bournonite     | $3(\text{Pb}, \text{Cu}_2)\text{S} \cdot \text{Sb}_2\text{S}_3$  | O     | 1.875 : 1 : 1.793 | $f \wedge f =$ | 56 8          | 63 48                               | $2a \cdot \frac{1}{2}c$                          |
| Freieslebenite | $5(\text{Pb}, \text{Ag}_2)\text{S} \cdot 2\text{Sb}_2\text{S}_3$ | M     | 1.703 : 1 : 1.580 | 92° 14†        | 60 48         |                                     | $a=b$  |
| Dufrenoyite    | $2\text{PbS} \cdot \text{As}_2\text{S}_3$                        | O     | 1.531 : 1 : 1.876 | $i \wedge i =$ | 66 18         |                                     | $a=c \cdot 2c$                                   |
| Jamesonite     | $2\text{PbS} \cdot \text{Sb}_2\text{S}_3$                        | O     | ? : 1 : 1.830     |                |               |                                     | $a=c \cdot 2c$                                   |
| Sartorite      | $\text{PbS} \cdot \text{As}_2\text{S}_3$                         | O     | 1.856 : 1 : 1.722 |                | 56 38         |                                     | $a=b \cdot \frac{3}{2}c$                         |
| Zinkenite      | $\text{PbS} \cdot \text{Sb}_2\text{S}_3$                         | O     | 1.794 : 1 : 1.709 |                | 58 17         |                                     | $a=b \cdot \frac{3}{2}c$                         |

M = Monoclinic. O = orthorhombic. R = rhombohedral.

In the majority of cases in the above table the change from the position given in Dana has been made by a simple interchange of the  $a$  and  $b$  axes and by multiplying the vertical axis in its new relation by a simple factor. The isomorphous relations of jordanite and meneghinite, studied by Miers,† Krenner,§ Schmidt|| and Groth¶ are not at all clear. The factor  $2\frac{2}{3}$  given for the vertical axis is a rather unnatural one, which if adopted would give to the forms observed on meneghinite very complicated indices. The axial ratio suggested by Schmidt,  $a : b : c = 0.4862 : 1 : 1.8465$ , would give by interchange of  $a$  and  $b$  and using the factor  $\frac{1}{2}$  for the vertical axis  $a : b : c = 2.0568 : 1 : 1.8984$  and  $m \wedge m' = 51^\circ 52'$ , values which show the widest variations of any in the table from polybasite. It will be noticed that the vertical axes of the arsenical

\* Min. Mag., x, p. 185, 1893.

\*\* Sitz. Ber. Akad. d. Wiss., Berlin, 1891, p. 697.

† Owing to the change of position of the axes, the inclination for jordanite becomes  $\gamma$  instead of  $\beta$  and for freieslebenite  $a$  instead of  $\beta$ .

‡ Min. Mag., v, p. 325, 1884.

§ Földt. Közl., xiii, p. 297, 1883.

|| Zeitschr. Kryst., viii, p. 613, 1883.

¶ Tabellarische Uebersicht, p. 33, 1889.

compounds pearceite, jordanite, proustite, dufrenoyite and sartorite are greater than those of the corresponding antimony compounds, while xanthoconite and pyrostilpnite form an exception to this rule, which may, however, be due to inaccuracy in the measurement of the small crystals of these exceedingly rare minerals. The relations shown in the table may be accidental, but the close approximation of the axial ratios to that of chalcocite would seem to indicate that the sulphide of the metal has had a controlling influence on the crystallization. Sternbergite,  $\text{Ag}_3\text{S} \cdot \text{Fe}_2\text{S}_3$  with  $m \wedge m = 60^\circ 30'$  and enargite,  $3\text{Cu}_2\text{S} \cdot \text{As}_2\text{S}_3$  with  $x \wedge x'' = 320 \wedge 320$  (twinning plane)  $= 60^\circ 17'$  might be added to the table.

Laboratory of Mineralogy and Petrography,  
Sheffield Scientific School, New Haven, March, 1896.

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ART. V.—*The Hydrology of the Mississippi*; by JAMES L. GREENLEAF, C.E.

A RIVER of the size of the Mississippi necessarily has many and important tributaries, with their individual peculiarities of watershed, channel, and variation in flow. Each of these tributaries exerts its proportionate influence upon the stream which is the resultant, and a knowledge of them is therefore essential to a study of the hydrology of the main river. For this reason, sixteen of the branches especially influential in forming the character of the Mississippi, have been selected for a brief discussion.

As a preliminary, it will be well to consider for a moment the point of view from which the engineering profession examines the hydrology of a watershed. Whatever the purpose that the engineer has in working upon a river, be it water power, water supply of towns, irrigation, the training of the current to prevent devastating overflows or to maintain a depth for navigation; in each and all of these problems two fundamental considerations force themselves upon his attention. They are the degree of regularity, and the amount of the volume of flow from the tributary country. Thus, in the south, the Mississippi River Commission and the Levee Boards find the flow volume a vital feature in their efforts to confine the stream in a definite channel. At the north, the Engineer Corps of the United States Army are constructing a system of reservoirs for holding back the freshets and aiding navigation upon the upper river during the season of low flow.

Another item of interest, if not of importance, is the amount of the annual rainfall and its distribution. Although the flow of the streams, or "run off" as it is sometimes called, depends upon the rainfall, yet it bears by no means a direct and simple relation to the latter. The percentage varies with the nature of the country, the climate, and the season of heaviest rainfall, from eighty or ninety down to less than five per cent. Merely

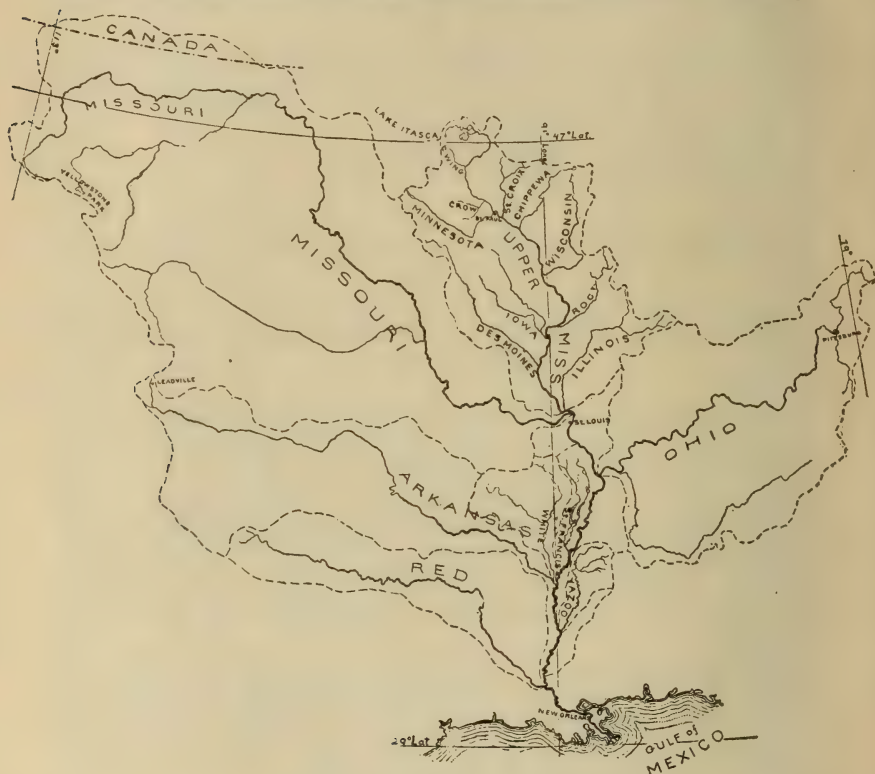


FIG. 1.

to suggest some of the causes of its variation, the following may be mentioned. A steep and rocky region will rapidly pour most of its rainfall into the stream. A level country, over which the water settles and flows off slowly, may expend nearly all in evaporation. A sandy soil absorbs the rain like a sponge as fast as it falls, to feed the never failing springs, and consequently gives a high ratio of flow; or, on the contrary, the water may sink too deep for that, and possibly make its first appearance in some far distant valley belonging to another watershed. A winter rain storm will perhaps all find its way



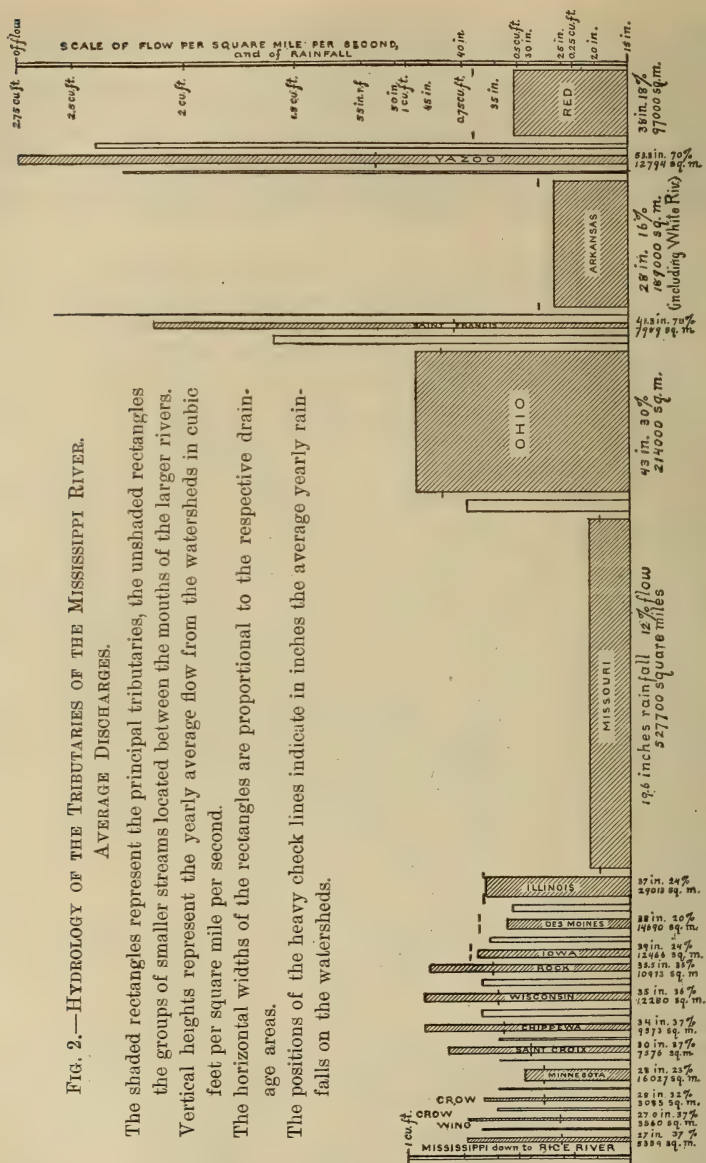
over the frozen ground to the water channels, and a summer shower may be entirely absorbed by the thirsty land and growing vegetation. In fact, the ratio of "run off" to rainfall is so uncertain, that engineers consider volumes of flow deduced merely from records of rainfall of small importance, as compared with a long series of actual gaugings of the stream. But gaugings are seldom available, and hence the percentage that the flow bears to the rainfall is of more than mere scientific interest.

From the foregoing it may be concluded that, in studying the hydrology of a watershed, the engineer considers the area of drainage, the rainfall and its distribution through the seasons, the temperature, the character of the region as influencing the percentage and regularity of flow, and, most valuable of all, actual gaugings of the streams—if he can obtain them.

The basis of this discussion of the Mississippi is a report by the writer upon certain water-powers for the Tenth Census of the United States. The data there given have been amplified to cover the flood and low water as well as the average discharge of the Mississippi and its tributaries, and have been brought up to date by study of the subsequent gaugings conducted by the Corps of Engineers of the United States Army. Acknowledgment is due to this source of information, without which any study of the river would be impossible, and also to the many individual members of the Corps from whom courteous replies have been received to letters of inquiry concerning details. It is believed that the conclusions here offered are an essentially correct statement of the conditions of flow pertaining to the Mississippi watershed. The yearly reports of the United States Corps of Engineers, which are awaited with interest, will either substantiate still further the diagrams here offered, or furnish data for their alteration.

Figure 2 illustrates some of the principal features of the branches selected as especially influencing the Mississippi. The shaded rectangles represent the watersheds in the order of their occurrence from the source to the mouth, and the unshaded rectangles the intermediate areas tributary directly to the main river. The horizontal widths of the rectangles are proportional to the respective drainage areas, and their heights show the yearly average flow in terms of cubic feet per square mile per second. The areas of the rectangles may therefore be said to give a measure of the relative influence of the tributaries upon the average discharge of the main stream.

The diagram exhibits the peculiarities of the tributaries, but fails to furnish an explanation, and that information we must seek for. It will be noticed on the diagram, that the rainfalls, shown by the horizontal lines, increase from the north toward



the south, attaining one maximum on the Iowa basin. Also, the main stream down to Rice River, the Crow Wing, Saint Croix, Chippewa, Wisconsin, and Rock, may be termed high flow streams. Their percentages of flow to rainfall are from thirty-

five to thirty-seven, and in this respect they are only equalled by some of the tributaries in the far south. The actual volume of flow, however, is not as great as the figures might lead one to infer, for the annual rainfall is slight, being over a portion of the tributary region only twenty-seven inches in depth. In consequence these streams yield a yearly flow of 0.625 cubic feet per square mile per second, rising to 0.928 cubic feet in the case of the Wisconsin, while the Ohio, for example, although only a thirty per cent stream, gives 0.953 cubic feet of average flow, because of its greater rainfall.

Why is it that the percentage of flow to rainfall for the rivers mentioned, is sufficiently large to raise them into the list of high flow streams in spite of their light rainfall? It may be due, in part, to the spring rainfall being slightly greater relatively to the summer rainfall for the first five hundred miles or so of the Mississippi than for the second, and to the later advance of warm weather at the upper waters causing a delay in evaporation, and in the demands of vegetation. But the principal reason must be sought in the character of the country drained. A sandy soil that absorbs the rain and yields it to the streams with comparatively little loss from evaporation is a feature of a large part of this region. Pine forests that check the dry winds and moisture-searching sun of summer also abound at the sources of the Mississippi, Saint Croix, Chippewa, and Wisconsin.

In contrast to the high flow tributaries is the Minnesota. This river has nearly the drainage area of the Mississippi above where the Minnesota enters it, but in the volume of flow does not approach to the importance of the latter. It is a true "prairie stream," running high at one season, and then dwindling with dry weather, or a cold winter, to almost nothing. Its percentage of average flow to rainfall is only twenty-three, and its average discharge is 0.474 cubic feet per square mile per second. The Iowa and Des Moines likewise flow from an open prairie country and are no better in ratios of flow, yielding only twenty-four and twenty per cent respectively, but in them the increased rainfall shows its effect. Upon these watersheds there is a rainfall of thirty-eight inches annually as against twenty-eight for the Minnesota, and the ten extra inches raise the rectangles considerably above that for the latter river.

The Illinois drains 29,000 square miles to the east of the Mississippi, and is the most important tributary met with thus far in passing down the river. Its rainfall, percentage of flow, and discharge per square mile happen to be almost precisely the same as for the Iowa. The drainage basin also is similar in many respects. The land is level, or gently undulating, but not quite so pronounced a prairie region as the country lying



west of the Mississippi. An extensive swamp drains into its head waters from Indiana.

Just below the Illinois is the mouth of the Missouri. Its drainage area is three times as great as that of the entire Mississippi above the junction. It rises in the heart of the Rocky Mountains and flows for nearly three thousand miles through mountain land and prairie. Greatly varying conditions of hydrology prevail within the limits of the watershed, but one fact stands pre-eminent: of all the branches of the Mississippi it makes the poorest record for the area it drains. If its flow was proportionately as great as from the Ohio, its discharge alone would equal the entire volume that passes New Orleans each year. The diagram illustrates the peculiar weakness of the Missouri, due primarily to its low average rainfall, and to the extremely small percentage of flow. Twelve per cent of less than twenty inches rainfall give only 0.178 cubic feet per square mile per second for the average discharge. It is well to remember, however, that these are averages, and that in flood the Missouri is a mighty torrent of muddy water.

A short distance below the mouth of the Missouri, the Ohio enters, with less than half the drainage area of the former, and more than the total yearly discharge. It reaches so far eastward that dwellers on the Atlantic coast look upon its upper waters as neighboring streams. Mountains and woodland cover a large portion of its basin. The rich, undulating farm lands of Ohio, Indiana and Illinois are tributary to it. The large average discharge is not due especially to the percentage of flow, for its thirty per cent is a moderate amount, but to the forty-three inches of annual rainfall. The warm moist air currents which flow from the Gulf region up the Mississippi valley have a decided tendency to the north and east rather than westerly, and this is chiefly the cause of the preponderance of the Ohio over the Missouri. The area of its rectangle in the diagram equals seven-ninths of the combined areas of all the rectangles preceding it, including the Missouri.

The Arkansas is another large river entering from the west, draining 189,000 square miles, and is in many respects a small imitation of the Missouri. Its average ratio of flow to rainfall is only sixteen per cent, and all that tends to raise its standing is the larger average rainfall of twenty-eight inches.\*

The Red River is the last important tributary of the Missis-

\* The White River, draining 28,000 square miles, has been included with the Arkansas in Figure 2. It is true that they enter the Mississippi together, but strictly speaking they are distinct rivers. It will be noticed that where it is more necessary, as in Figure 4, the Arkansas and White are given separate treatment.

ssippi. It flows from the west, bringing the drainage of 97,000 square miles. It maintains not only a slightly better ratio of flow than the Arkansas, but is subject to a decidedly higher rainfall. The former is eighteen per cent, and the latter averages over thirty-eight inches annually. As a result, the Red River yields an average discharge of 0.515 cubic feet per square mile per second. The mouth of the Mississippi is, in a hydrological sense, situated where the Red River enters it, for at this point the Atchafalaya Bayou taps the river and draws off a considerable share of its waters.

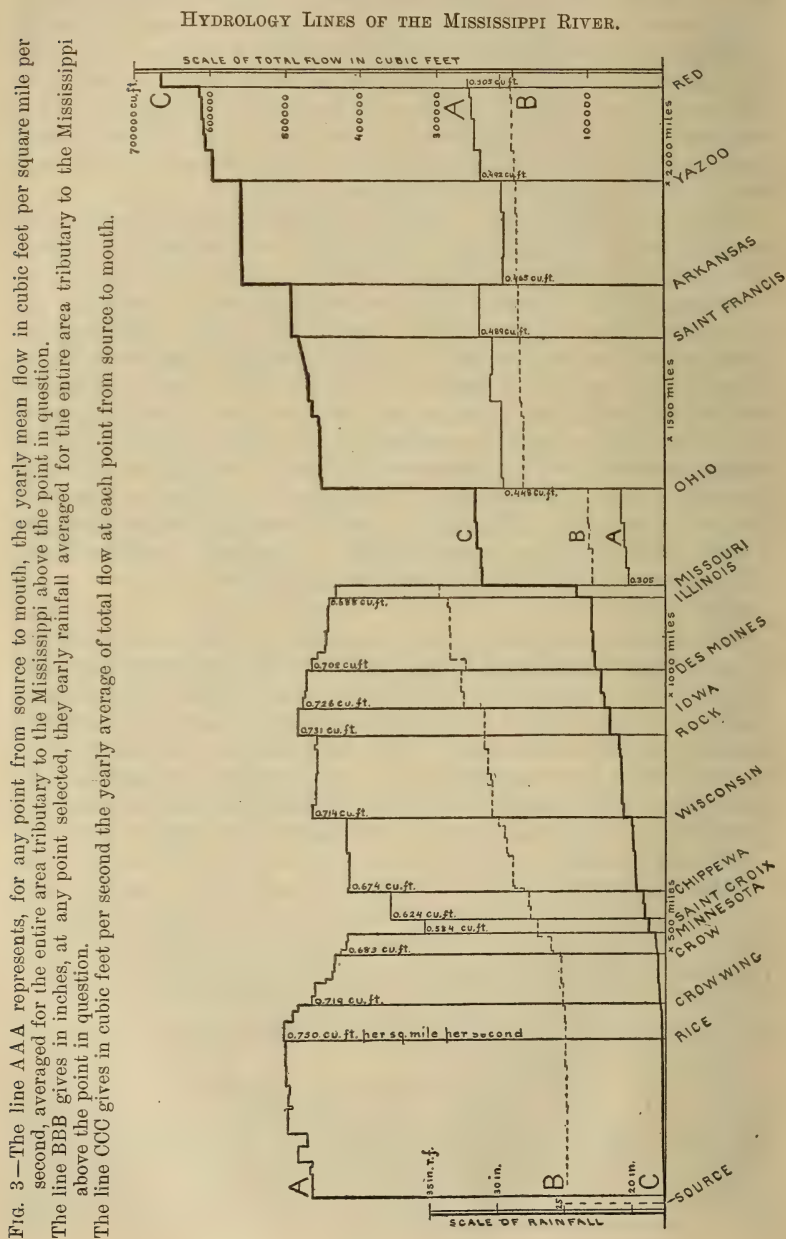
It will be noticed that two rivers of marked peculiarities are represented in the diagram. The Saint Francis and the Yazoo are the largest of several streams entering in the vicinity of the Arkansas and the Red, which are comparatively small and do not extend far to the west or east. They are consequently directly in the track of the heavy rainclouds from the Gulf. The rainfall upon their watersheds either sinks rapidly into the sandy soil and thus escapes evaporation, as is the case on a large part of the Yazoo watershed, or else flows quickly into the swamp reservoirs that characterize both the Yazoo and the Saint Francis. Hence the ratio of flow is as high as seventy per cent of the rainfall, and the yearly average flow amounts to 2.130 cubic feet per square mile per second, for the Saint Francis, and to 2.749 cubic feet for the Yazoo.

The second diagram, giving the average flow and rainfall lines of the Mississippi River, follows directly from the diagram of the tributaries. Its special interest lies in the information it affords as to the resultant effect which the branches have upon the main river. The line of flow, "CCC," gives in cubic feet per second the yearly average of total flow at each point from source to mouth. This line will be seen to corroborate a previous statement concerning the large discharge of the Ohio River.

The line "BBB" gives in inches, at any point selected, the yearly precipitation in rain and melted snow, averaged for the entire area tributary to the Mississippi above the point in question. If the point selected is at the mouth of some inflowing river, the line shows the average rainfall above its tributary watershed, and also the effect of including this watershed in the general average.

The line "AAA" is by far the most significant of the three in the study of the hydrology of the Mississippi. It represents for each point from source to mouth the yearly mean flow in cubic feet per square mile per second, averaged for the entire area tributary to the Mississippi above the point in question. If the point selected is at the mouth of some inflowing river,

the line shows the average flow from the area above its tributary watershed, and also the effect of including this watershed





in the general average. The line "AAA" is not a simple exponent of totals, as is the line "CCC" of total flow. It is a function of the varying average of rainfall, the varying tributary area as the branch streams are passed, each with its large or small watershed, and the varying percentage of flow to rainfall in force upon these side basins. In the use of this line area enters as a factor of equal importance with volume in the study of the hydrology of the river.

It will be noticed that the effect of any one tributary area upon the line "AAA" is much less marked toward the mouth of the Mississippi than would be the case if its watershed were located at the upper waters. The obvious reason is that it has the weight of all the large areas tributary above it to work against before it can influence the general average. If, for example, the Yazoo and Wisconsin, which have nearly equal drainage areas, were to change places, the latter would cause but slight alteration in the lower end of the line, while the Yazoo, in its new position, would raise the line to a flow of over one cubic foot per second.

It remains to see what general deductions the diagram affords. In the first place, it shows that there is abundant reason for the popular division of the river into the upper and lower Mississippi. The line "CCC" gives the upper river a gradual increase of volume to where it joins the Missouri. At that point begins the lower Mississippi, and the great accretions from the Missouri, and especially the Ohio River, immediately force the line to a higher level. Then the Arkansas and Red Rivers make the rate of increase much greater than for the upper Mississippi. But the line "AAA" exhibits in a decided manner a difference still more fundamental between the upper and the lower divisions of the river. A glance along this line from source to mouth will make apparent the great depression that it undergoes from the Missouri south. The upper river is a high flow stream throughout its length. The lower river belongs just as decidedly with the low flow class.

The depressing effect that the prairie streams have on the Mississippi is marked. Wherever a drop occurs in line "AAA" it is caused by a river upon which prairie influences prevail. The Crow Wing, Crow, Minnesota, Iowa, Des Moines and Illinois exert such effect. The Arkansas causes a decided drop in spite of the large area above that its watershed is averaged with. The Red River alone, of all its class, does not lower the line. This is due in part to its large rainfall, and partly to the line being already well pulled down by the Arkansas to meet it. As for the effect of the Missouri, it is deserving of special notice. A profound drop in line "AAA" occurs at its mouth. If it were not for this, the main river would continue a high

flow stream to the Gulf. The extremely small rainfall and percentage of flow of the Missouri, coupled with its half million square miles of drainage area, determine the main river to its mouth. The pronounced high flow character of the Ohio results in the lifting of the line "AAA" at once through forty per cent of the drop occasioned by the Missouri, but even the Ohio, magnificent as it is in drainage area, and with a high rank among the tributaries for its volume of flow, cannot redeem the character of the Mississippi after its debasing union with the Missouri River.

It is interesting to notice that the dual action of the Missouri and Ohio has its imitation toward the north. The low flow Minnesota causes, on a small scale, a drop in the line "AAA" similar to that produced by the Missouri, and below it the Saint Croix and Chippewa are the first of a series of branches culminating in the Rock River, which more than make good the depression.

The influence of the heavy rainfall and large percentage of flow in the south is shown by the gradual rising of the line "AAA." The Saint Francis and Yazoo and lesser streams, draining all together only 43,000 square miles, make a perceptible headway in the averages, even against the inertia of all the vast drainage area lying to the north, east and west of them. If their condition of rainfall and flow prevailed over the entire 1,259,000 square miles forming the Mississippi watershed, the average discharge would be fully three million cubic feet per second ; more than forty times its actual volume. These figures indicate what the Mississippi, grand river that it is, might be if the trade winds and moist air currents from the Gulf of Mexico did but sweep the semi-arid regions to the northwest, and pour a plenteous rainfall over their vast extent.

Thus far the discussion has been confined to a study of average flow, and is therefore open to the criticism that all averages are liable to, for it states nothing concerning the variations of flow characteristic of the rivers. Indeed, the average flow may even be looked upon as a theoretical quantity, inasmuch as it has no real and tangible existence, except for a few brief periods during the year. No apology need be offered for its presentation, however, for a study of averages is an important aid to the understanding of the actual relation of flow which the rivers bear to one another. Attention will now be given to the variations in the volume of flow of the tributaries of the Mississippi, and the relations which these variations bear to the climatic and topographical features of the watersheds. Figure 4 and the subsequent notes present particulars concerning rain-

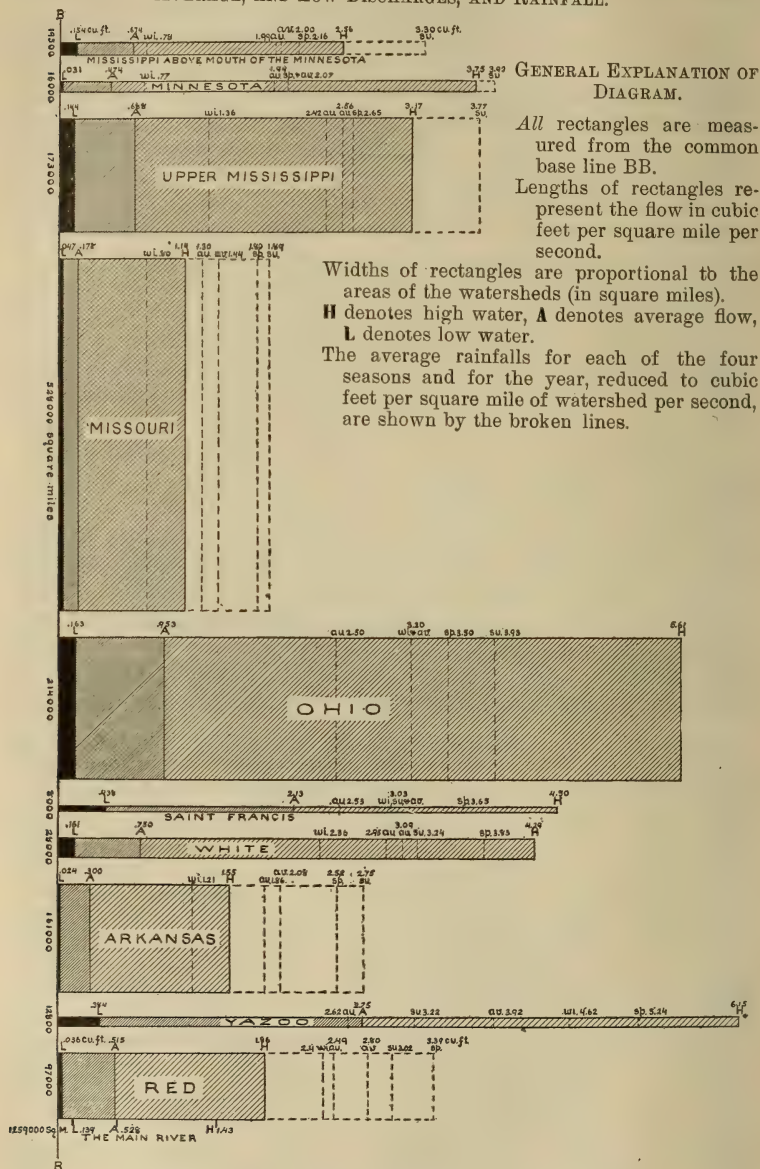
fall, minimum and maximum flows, and the time variations in the amount of flow for each of the principal tributaries.\*

A glance over the diagram makes wide differences apparent. The Ohio, Yazoo, Saint Francis and White have comparatively large flood flows per square mile per second. The Arkansas, Red, Missouri and Minnesota have especially small flows per square mile per second. The determining causes for these and other differences are the amounts of rainfall on the watersheds, the distribution of these amounts through the seasons, the degree of storage of winter precipitation to be liberated in the melting of the snow and ice at spring time, the nature of the country and vegetation, and the amount of natural storage in the form of lakes and swamps. It should be borne in mind that the southern rivers of limited drainage area have a heavy rainfall, and a large amount of this occurs in the winter and spring, when evaporation and the demands of vegetation are slight. The same is true of the Ohio watershed, because of the marked tendency for the moisture laden air-currents to flow over it to the northeast in the early months of the year. For these reasons one would expect the southern rivers to carry high rates of flood-volume as compared with streams differently conditioned. The tributaries farther north, on the contrary, and particularly the Arkansas and Missouri, which extend their lines of drainage far westward, have average amounts of annual rainfall greatly below that of the Ohio, for example, and of this the greatest activity occurs in summer, when the tendencies are strongest to absorb and evaporate it

\* Adverse criticism is almost inevitable when one puts in concrete form conclusions from a series of data which are so liable to various interpretations as are gaugings of the flow of rivers. It is very largely a matter of judgment as to what shall be taken for the characteristic minimum flow or maximum flow, and one's impression of the time of occurrence of the annual greatest flood, or of low water, is apt to be influenced by some special case which has fixed itself on the mind, rather than by impartial averages. It is the latter that I have tried to follow. I hope to disarm adverse criticism by frankly holding myself open to conviction regarding the conclusions offered, and by stating that they are the result of a somewhat extensive study of all the available gaugings by the United States Engineer Corps. checked and compared with the opinions so kindly given by a number of the officers stationed along the rivers. The aim has been to give the discharges at decidedly low and high water, but at the same time to avoid using any special and extreme case as a criterion. It is proper to state that discharge data concerning the Yazoo and, above all, the Saint Francis, are especially meagre and more or less uncertain. Capt. Willard's gaugings upon the Yazoo are about the only reliable figures to start with. The Saint Francis is so liable to overflow from the main river as to make gaugings of it well nigh impossible of interpretation. Fortunately the climatic conditions are quite uniform over the region of country concerned, giving some authority to a comparison between neighboring watersheds of limited extent. Therefore, by comparing first the Yazoo and White, giving due value to the proportions of upland and bottom land, and then applying the results to the Saint Francis, and checking by a proper balance between the three rivers, results have been obtained which I believe to fairly represent the truth.



FIG. 4.—HYDROLOGY OF THE TRIBUTARIES OF THE MISSISSIPPI RIVER, HIGH, AVERAGE, AND LOW DISCHARGES, AND RAINFALL.



**Mississippi above the Minnesota.** *High.*—Rise begins in early April, due to Spring rains and melting snow—reaches a max. in end of April to May, and often is the max. of the year. Effect of melting ceases, but rains maintain a fair stage. Decided rise in June to July, due to rains—sometimes the highest of the year. Generally a brief Fall freshet.

*Low.*—The low water of Fall occurs in August to Nov.—usually lowest in end of Sept. to mid. Oct. Lowest water of year in end of Nov. to end of Dec., due largely to freezing of the ground.

**Minnesota.**—Practically the same in period of rise and fall as the Mississippi above it, but much more fluctuating in amount, because of the comparatively few lakes and swamps, and more open prairie on its watershed.

**Upper Mississippi (down to Missouri River).** *High.*—Rise begins in Feb., due to rains and melting snow. A good stage maintained well into July. Usually two occasions of especially high water. The smaller may occur any time from latter part of Feb. to end of March, due to rains and melting snow. The greater may occur any time from April to July, due to rains and somewhat to melting snow. There is often a brief Fall freshet.

*Low.*—The lowest water of the Fall occurs in Aug. to Oct., generally in Oct. The lowest of the year is in Dec., due largely to freezing of the ground.

**Missouri.** *High.*—The volume of flow increases from early in Feb. on, reaching a max. in April, due to rains and melting snow. Owing to the large differences of elevation on the watershed, melting snow influences the stage of the river until Aug. A fall occurs in May, as the bulk of the snow disappears. Then there is a rise in June to the max. for the year, falling in July and Aug.

*Low.*—The river runs low in Sept., Oct. and Nov., and in the latter part of Nov. into Dec. occurs a sudden drop to the lowest stage of the year, due to freezing of the ground.

**Ohio.** *High.*—The river usually begins to rise in the latter part of January and is liable to maintain a fair stage until into July. In latter part of Feb. on, into the latter part of March, occurs the max. rise of the year, due to winter and spring rains and melting snow. Again, in April to middle of May is the height of a secondary rise, due to rains solely. The Fall rains cause an occasional rise in Nov.

*Low.*—The low water is in August through to Jan., and the lowest is any time from the first of Oct. to the middle of Nov.

**Saint Francis.** *High.*—The river rises to a good stage in the middle to end of Jan., diminishing through May. The highest stage usually occurs in the latter part of March.

*Low.*—Low water runs through Sept. to Dec., usually reaching the lowest point in the end of Oct. to the end of Nov.

**White.** *High.*—There is usually a good stage from Jan. to June, a fall sometimes intervening. The highest water may occur any time between those limits, with the chances in favor of its coming in May.

*Low.*—Low water occurs from July into Dec., and the lowest stage of the year from Sept. to Nov., especially in Nov.

**Arkansas.** *High.*—A good stage of water is liable from Jan. to June. A max. occurs in Feb., and again in April or May, and the chances are about even in the long run for either of these being the max. for the year. There is often a brief freshet in the Fall.

*Low.*—The river falls in July, and, except for Fall freshet, runs low into Dec. Lowest stage of the year is liable from end of Sept. to middle of Nov.

**Yazoo.** *High.*—There is a good stage of water from Jan. to June or July, culminating usually in April. An irregular and occasional rise occurs any time from Aug. to Dec.

*Low.*—The river runs low as a rule from July through Dec., reaching a minimum in the latter part of Oct. to the end of Nov.

**Red.** *High.*—The river rises in Jan. and holds a fair stage until into June. The highest water of the year may occur any time from Feb. to May, and probably in April to May. There is an occasional short rise in late Summer or Fall.

*Low.*—The river falls in July and runs low as a rule until in Dec. The lowest water for the year may occur in Sept., Oct. or Nov.

**The Main River.** *High.*—The river begins to rise early in January, and attains a max. stage usually in latter part of April or May, falling in June, July and August.

*Low.*—The low water occurs from Sept. on to the end of the year, reaching the lowest point, as a rule, in Nov.

Table of Rainfall and Discharge Data for the Principal Watersheds of the Mississippi System.

| WATERSHED.  | RAINFALL. |                                |         |                                |         |                                |         |                                |         |                                | FLOW PER SECOND.           |                       |                            |                       |                            |                       |
|---|-----------|--------------------------------|---------|--------------------------------|---------|--------------------------------|---------|--------------------------------|---------|--------------------------------|----------------------------|-----------------------|----------------------------|-----------------------|----------------------------|-----------------------|
|   | Annual.   |                                | Spring. |                                | Summer. |                                | Autumn. |                                | Winter. |                                | Minimum.                   |                       | Average.                   |                       | Maximum.                   |                       |
|   | Inches.   | Cu. ft. per sec. per sq. mile. | Inches. | Cu. ft. per sec. per sq. mile. | Inches. | Cu. ft. per sec. per sq. mile. | Inches. | Cu. ft. per sec. per sq. mile. | Inches. | Cu. ft. per sec. per sq. mile. | Total in 1000's of cu. ft. | Cu. ft. per sq. mile. | Total in 1000's of cu. ft. | Cu. ft. per sq. mile. | Total in 1000's of cu. ft. | Cu. ft. per sq. mile. |
|   | Depth.    |                                | Depth.  |                                | Depth.  |                                | Depth.  |                                | Depth.  |                                |                            |                       |                            |                       |                            |                       |
| Mississippi<br>above mouth of Minnesota<br>Riv. (19,500 sq. miles) ----     | 27.2      | 2000                           | 7.1     | 2158                           | 10.7    | 3296                           | 6.8     | 1994                           | 2.7     | 0.780                          | 3                          | 0.154                 | 13                         | 0.674                 | 50                         | 2.56                  |
| Minnesota<br>(16,000 sq. miles) -----                                       | 28.0      | 2061                           | 7.0     | 2070                           | 11.8    | 3476                           | 6.6     | 1944                           | 2.6     | 0.772                          | 0.5                        | 0.031                 | 7.6                        | 0.474                 | 160                        | 3.75                  |
| Upper Mississippi<br>above mouth of Missouri<br>Riv. (173,000 sq. miles) -- | 34.7      | 2555                           | 9.0     | 2650                           | 12.8    | 3769                           | 8.2     | 2415                           | 4.6     | 1.355                          | 25                         | 0.144                 | 118                        | 0.688                 | 550                        | 3.17                  |
| Missouri<br>(528,000 sq. miles) -----                                       | 19.6      | 1443                           | 6.1     | 1796                           | 6.4     | 1885                           | 4.4     | 1296                           | 2.7     | 0.795                          | 25                         | 0.047                 | 94                         | 0.178                 | 600                        | 1.14                  |
| Ohio<br>(214,000 sq. miles) -----   | 43.1      | 3173                           | 11.9    | 3504                           | 11.8    | 3925                           | 8.5     | 2503                           | 10.9    | 3.210                          | 35                         | 0.163                 | 204                        | 0.953                 | 1200                       | 5.61                  |
| St. Francis<br>(30,000 sq. miles) -----                                     | 4.3       | 3041                           | 12.4    | 3652                           | 10.2    | 3004                           | 8.6     | 2533                           | 10.3    | 3.033                          | 23.5                       | 0.438                 | 17                         | 2.130                 | 436                        | 4.50                  |
| White<br>(28,000 sq. miles) -----   | 42.0      | 3092                           | 13.0    | 3828                           | 11.0    | 3239                           | 10.0    | 2945                           | 8.0     | 2.356                          | 4.5                        | 0.161                 | 20                         | 0.750                 | 120                        | 4.29                  |
| Arkansas<br>(161,000 sq. miles) -----                                       | 28.3      | 2082                           | 8.6     | 2518                           | 9.3     | 2748                           | 6.3     | 1864                           | 4.1     | 1.207                          | 4                          | 0.024                 | 48                         | 0.300                 | 250                        | 1.55                  |
| Yazoo<br>(13,000 sq. miles) -----   | 53.3      | 3924                           | 17.8    | 5239                           | 10.9    | 3222                           | 8.9     | 2621                           | 15.7    | 4.615                          | 35                         | 0.384                 | 35                         | 2.749                 | 480                        | 6.15                  |
| Red<br>(97,000 sq. miles) -----   | 38.3      | 2798                           | 11.5    | 3386                           | 10.2    | 3019                           | 8.4     | 2485                           | 8.2     | 2.400                          | 3.5                        | 0.036                 | 50                         | 0.515                 | 180                        | 1.86                  |
| Mississippi<br>above its mouth (1,259,000<br>sq. miles) -----               |           |                                |         |                                |         |                                |         |                                |         |                                | 175                        | 0.139                 | 664                        | 0.528                 | 1800                       | 1.43                  |

<sup>1</sup> Probably much exceeded at times.<sup>2</sup> Obtained from a comparison of the Yazoo and White. <sup>3</sup> Derived chiefly from gaugings by Captain Willard; checked by comparison with the White.<sup>4</sup> Result chiefly of a comparison with the White, allowing for differences of rainfall and topography. —Somewhat uncertain.



before it reaches the streams. Again, heavy rainfalls are liable to be somewhat local in their extent, when the entire drainage basin of a large river is considered. In the case of the Missouri, for instance, while the early spring rains are falling upon the regions near its mouth, the upper and elevated watershed is supplying comparatively nothing to the flow. The natural tendency of such a condition as this is to pull down the average rate of the high flow per square mile for an extensive drainage area. On account of the above reasons it is not surprising that the northern and large western tributaries of the Mississippi should carry comparatively small rates of maximum flood volume per square mile. To be sure, they have an advantage over the strictly southern rivers in drawing upon large quantities of melting ice and snow which may concentrate the winter precipitation in a brief period of melting. The winter precipitation upon their basins, however, is far lower in rate than for the other three seasons of the year, and the melting occurs chiefly before the heaviest rainfalls, which tend toward the late spring or summer. There result from this simply two freshets, the first due to melting aided by rains, and the second due principally, if not entirely, to rains alone. Between these two freshets occurs a more or less pronounced tendency to a merely fair or average stage of water.

Upon turning to consider the rates of low flow and their causes one is confronted at once with the much smaller annual rainfall upon the entire northern and western portion of the Mississippi watershed. Behind this prominent fact are a number of minor considerations. Thus, the proportionate, and probably the absolute loss from evaporation and absorption by vegetation is greater for regions with a light, than for those with a large rainfall. The proportion of natural storage per square mile in the form of lakes and swamps is smaller for large than for small watersheds. Finally, the climatic conditions are such over the major part of the Mississippi watershed, that the period of light rainfall in the autumn dominates a wide extent of country. So, while it is true that all portions of any one of the large watersheds will not at any one time be giving their maximum flood volume for the year, the converse is not true, for they may uniformly concur in yielding their minimum flows. The entire watershed of the longest tributary of the Mississippi, for instance, may at one and the same time be suffering from a greatly diminished rainfall, and one part of the area cannot be counted upon to maintain the flow while another part is subject to drouth. The above causes readily account for the exceedingly low flow per square mile of 0.047 cubic feet per second from the Missouri, and 0.024 cubic feet from the Arkansas, and for the uniformly low rate of minimum

flow from all the smaller streams in the northwestern part of the Mississippi watershed.

Passing now to the extreme upper waters of the river, the upper Mississippi above the mouth of the Minnesota, and the Minnesota itself show certain interesting and instructive differences. The total amount and the distribution of the rainfall is nearly the same for both, the Minnesota having a slightly more pronounced concentration of rainfall in the summer months. The Minnesota is preëminently a prairie stream, whereas the main river is characterized, to an unusual degree, by lakes and swamps. It is not strange, therefore, that the flood-flow per square mile is nearly fifty per cent larger from the Minnesota than from the main stream. Neither is it to be wondered at that the Minnesota dwindles away to 0.031 cubic feet per square mile per second in low water, exhibiting the true character of a prairie stream, while the natural lakes and swamps of the main river hold it, in spite of the low rainfall, up to 0.154 cubic feet per square mile per second.

The upper Mississippi, at the point where it unites with the Missouri to form the lower river, takes high rank in the matter of rates of flow, in spite of its average climatic conditions being essentially those already described as pertaining to the northern and western tributaries. Its high rate of low flow is largely the result of the natural storage in the immense number of lakes and swamps in the States of Minnesota and Wisconsin. This storage affects to a marked degree the main river above St. Paul, the Saint Croix, Chippewa, Wisconsin, and other tributary streams. As a result, these rivers withstand very successfully the depressing effect of the prairie streams like the Minnesota, which enter from the west, and they maintain the low flow at 0.144 cubic feet per second per square mile.\* But not alone in its low flow as compared with the climatic conditions, is the upper Mississippi noticeable. Although its average annual rainfall is slight, yet it has heavy summer rains widely enough distributed over its 173,000 square miles of watershed to hold it well up toward the ranks of the high flood-flow tributaries. Also, its spring melting is sufficiently concentrated in point of time to have a very important influence upon the records of flood volume.

The Ohio demands special mention because of pronounced activity among its fellow tributaries. In a hydrological sense

\* Attention is here called to the fact that this paper is written throughout with reference to the natural conditions of the Mississippi drainage; the conditions which would pertain if the artificial storage works installed by the United States Government at the sources of the river were not existing. These works, uncompleted as they are, have resulted in maintaining a stage at St. Paul during the low season considerably more than a foot above the natural conditions of the river.

it is the ruling tributary of the Mississippi system. Although it has less than half as large a drainage area as the Missouri, yet its low, high, and average flows all exceed in total amounts the like volumes from the Missouri. In rates per square mile, these flows are only exceeded in the cases of certain southern rivers. In fact, the Ohio is rightly classed with the southern rivers, even granting that the annual melting of snow and ice is a prominent feature upon its basin. It has been pointed out that upon most extended drainage areas, the rate of high flow is pulled down by the averaging of districts where the rains may be falling, with regions that happen at that time to be comparatively dry. Not so for the Ohio. There is a strong tendency for moisture-laden air to be whirled in broad sheets over the watershed clear to the Alleghanies, and deposit heavy rainfalls during the same month over nearly the entire length of the basin. When this is taken into account with the relatively large average rainfall of 43 inches, and with the fact that the winter rains are only slightly less in amount than those of spring, the greatest of the year, and occur at the time when the snow and ice are going out, it is easy to understand why the Ohio should tower far above the other large tributaries of the Mississippi in its rate of high flow. That the Ohio is above even the upper Mississippi in its rate of low flow, is due primarily to its higher annual rainfall, and also to its important southern branches extending into a region of considerable autumn rainfall.

The lower Mississippi, the main channel into which all the tributaries flow, claims final attention. It is the resultant of these tributaries, but a resultant in which the element of time is a potent factor. If all the tributaries were high and low together, it would be easy to compute the high flow or low flow of the main stream by a simple process of summation. Owing, however, to a lack of unanimity among the streams in this respect, it is an exceedingly complicated and, in fact, impossible task to reason out conclusions concerning the flow of the main river simply from the general data for the tributaries. The tributaries do conspire to a considerable degree in producing the low stages of the main river, for the area of light rains in the fall is very widely extended over the Mississippi watershed. All the rivers are not at their lowest during the same time, however, for if they were the aggregate flow would be only 110,000 cubic feet per second, whereas the low water discharge of the Mississippi may be taken at 175,000 cubic feet per second, although lower gaugings have been recorded.

Fortunately for the well-being of the dwellers within the Mississippi valley, the tributary streams differ very widely in their times of flood. A simple calculation shows that if high



water occurred simultaneously with them all, the main river would have to carry over three millions cubic feet of water per second to the Gulf. As a matter of fact, it is an extremely rare coincidence for more than two of the large tributaries to be at their highest yearly stages at the same time. The greatest annual flood upon the Ohio, for example, has disappeared before that from the Missouri reaches the Mississippi. Thus the aggregate in the main river is kept down, so that 1,800,000 cubic feet per second may be considered a large flood discharge from the Mississippi. The combination of conditions is such that the lower river usually reaches its maximum volume for the year in April or May, and its lowest stage in October or November. The diagram shows, by a convenient comparison of rates of flow per square mile per second, the resultant effect of all the tributaries upon the main river. The rate of low flow, 0.139 cubic feet per square mile per second, is fairly well up, in spite of the downward pull given by the Missouri and Arkansas. The rate of high flow is kept down to 1.43 cubic feet per square mile per second,—which is only surpassed in smallness in the case of the Missouri,—by the above mentioned lack of coincidence in the times of flood from the various tributaries.

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ART. VI.—*Preliminary Note on the Relations of Certain Body-plates in the Dinichthyids*; by C. R. EASTMAN.

THANKS to the energy and skill of the local Ohio collectors in bringing together and developing fresh material, and to the painstaking descriptions of Newberry, Claypole, Wright and others, palæontologists have gradually become familiar with the principal features of Dinichthyid anatomy. Few chapters in the history of American palæontology are more interesting or instructive than that relating to the discovery and systematic fitting together of the detached parts, as rapidly as each new piece was brought to light, until finally almost the entire skeleton of these huge *Arthrodira* has been accurately reconstructed. For skill in determining isolated fragments and assigning them to their natural position, and for sagacity in tracing out the homologies with European Coccosteans, the work of these authors leaves nothing to be desired; and so thoroughly has every scrap of material been overhauled and scrutinized in the search for new evidence, that the structural details which still remain to be completed are relatively insignificant.

The object of the present paper is to communicate a slight

amount of additional evidence regarding the body-covering of the *Dinichthyids*. It is intended first to give a brief description of two plates which complete the median ventral armor of *Titanichthys*; second, to locate a plate of *Dinichthys* which has been known for a long time in a more or less imperfect condition, but whose exact relationships have never been definitely determined; and third, to call attention to the peculiar "nail-head" termination of the median dorsal shield in *Dinichthys*. The illustration of the parts presently to be described, together with more detailed observations on the structure of the *Dinichthyids*, is deferred until another time.

The material upon which the following notes are based was brought together by that indefatigable collector, Mr. Jay Terrell, of Oberlin, Ohio. It is all from the Cleveland Shale of Lorain County, Ohio, and is now preserved in the Museum of Comparative Zoology at Cambridge, Massachusetts.

*Median ventral plates of Titanichthys*.—Three perfectly preserved specimens afford a complete insight into the structure of the median portion of the plastron in *Titanichthys*, and we may assume that essentially similar elements were present in *Dinichthys*. Heretofore only one element has been provisionally assigned to the ventral surface of *Titanichthys*. Newberry mentions such an one, but was disposed to regard it as the equivalent in itself of the five distinct plates which constitute the plastron of *Coccosteus*.<sup>\*</sup> There can be no doubt as to the identity between this plate and the one figured by Clappole in Volume VII. of the *Palæontology of Ohio*,<sup>†</sup> which is also provisionally referred to *Titanichthys*. The third specimen is that examined by the writer; and it confirms Clappole's determination of the genus, and also his identification of it as a median ventral. This specimen is more perfect in outline than Professor Clappole's, and shows distinctly a wide impressed area on the four sides of the lozenge, formed by the overlapping margins of the anterior and posterior pair of ventrals, thus proving that the plastron of *Titanichthys* was constructed on the same general plan as in *Dinichthys* and *Coccosteus*.

There are two unique specimens in the Terrell Collection representing the anterior median ventral. The larger plate is 28<sup>cm</sup> long, and 18<sup>cm</sup> wide at the base. It is perfectly symmetrical; and, as seen from the dorsal side, lanceolate in outline, and traversed by a low median longitudinal ridge. This ridge merges with a pair of transverse elevations of moderate size at the major end of the plate, thus forming an inverted T in

<sup>\*</sup> "Nothing corresponding to the plastron of *Dinichthys* and *Coccosteus*, composed of five distinct plates, has been found associated with the other bones of *Titanichthys*, but instead, a single large triangular plate, which may have been its representative."—Newberry, *J. S.*, *Palæozoic Fishes of North America* (Monogr. U. S. Geol. Survey, No. XVI, 1889), p. 132.

<sup>†</sup> Plate XL, Figure 1. "Ventre-median plate?"

relief. As seen from the ventral aspect, the form is suggestive of the nasal plate in *Dinichthys*, owing to the semicircular compression of the border around the head of the T. This plate was overlapped for three-fourths of its length by the anterior ventrals, as is also the case in *Coccoosteus*.

*Posterior dorso-lateral plate.*—This element of the dermal skeleton is represented in the collection by three perfect specimens pertaining to the left side, and a fragmentary one from the right side. As already remarked, portions of this plate have long been known, Newberry having mentioned it as early as 1875.\* The greater portion of two such plates is figured by the same author in his Monograph† under the designation of “post-clavicular(?) plates.” In the body of the work (p. 142) this element is described as a “triangular bone with which I have long been familiar, but I am not yet able to fix with certainty its position on the body.”

Newberry suggested two places where this bone might have fitted on: one behind and overlapped by the suborbital plate, the other somewhere between the median dorsal and the antero-dorso-lateral (“suprascapula”). This latter position he regarded as the more probable, although hesitating to express himself decidedly on this point. If the true relations of the plate had been clear in Newberry’s mind, he would have designated it by its right name in the letterpress, and would not have styled it the “post-clavicular” in the legends for Plate VI.

A study of the material in the Museum of Comparative Zoology has convinced the writer of several things, as follows: The specimens figured by Newberry are incomplete, over 20<sup>cm</sup> being wanting from either end; the “free margin” is not straight, but gently arcuate from end to end, and is indented for a certain portion of its length by a contiguous plate (postero-lateral); the surface is not plane but warped, and on the under side it is thrown into a few parallel undulations, the axes of which are transverse with respect to the main axis of the body when the plate is oriented in its natural position.

The plate in question is the *postero-dorso-lateral*. Newberry’s figures 2 and 2a of Plate VI. are rights and lefts respectively;‡ to bring them into their natural relationships it is necessary to rotate them about their centers until their upper (anterior) extremities are inclined toward one another at an angle of about sixty degrees, and then separate them at a distance equal to the width of the median dorsal shield. In this position it will be noticed that the regular curve of the

\* Palæontology of Ohio, vol. ii, p. 32.

† *op. cit.*, Plate VI., Figures 2, 2a.

‡ These relations are reversed by Newberry; hence the figures must be interchanged in position after they have been rotated so as to include the angle above specified between their free margins, which are here represented as parallel.



postero-lateral margin of the median dorsal, and the curve of the overlapped margin on the lower portion of the plate under discussion will fall together, on superimposing the one upon the other. The prolongation of this curve is observable on the inner margin of the suprascapula, where the same is overlapped by the median dorsal. In other words, the superincumbent margin of the median dorsal leaves an impressed area on the antero- and postero-dorso-laterals, by means of which the relative positions of these three plates can be accurately determined.

On examining the postero-dorso-lateral, it will be noticed that the curve formed by the overlapping margin of the median dorsal is intersected nearly at right angles by another, longer, more ragged, and more deeply incised contour-line than the first; this marks the posterior boundary of the antero-dorso-lateral. The sensory canal system of the latter plate is continued on to the postero-dorso-lateral, sometimes as a single and sometimes as a double furrow, and furnishes another convenient clue to the orientation. The indented area already referred to on the so-called "free margin" of the plate was formed by the postero-lateral; and it is possible to reconstruct the form of the laterals from their imprints upon the plates annectant to them above and below, their curvature being indicated by the clavicles. It is to be hoped that by this means some of the unidentified plates existing in various museums may be recognized as the missing laterals.

From the above it will be seen that every plate present in the body armor of *Coccoosteus* has its representative in *Dinichthys*, and that the conditions of overlap and underlap are the same in both forms.

*Median dorsal plate* ("*Dorsal shield*").—The configuration of the posterior ridge on the under surface of this plate is well shown in a number of specimens belonging to the Terrell and Allen collections, two of which show that its inferior extension is greater than has been supposed. A preparation of these particular specimens resulted in the exposure of a deep spoon-shaped cavity at the extreme end of the terminal process on its dorsal aspect. The concavity is slightly emarginate below, and is continued up the ventral side of the process in the form of two broad, shallow depressions, which rapidly become narrower and deeper, so as to form well-marked channels. These gradually disappear, however, after traversing the lowermost portion of the inferior keel for a considerable distance. Corresponding to the ventral furrows are two dorsal, which extend from the bowl of the spoon along the 'handle' as far as the posterior margin of the dorsal shield proper. Here the terminal process broadens out on either side, and its roughened or striated upper surface evidently served for mus-

cular attachment. In contrast to this, it should be noted that the surface of the spoon-shaped concavity is perfectly smooth.

The question naturally arises, what purpose could this terminal structure have subserved? Was it in relation with the muscular system of the body, or for the support of a movable dorsal spine, such as is found in the recent Siluroids, for instance? It is easy to believe that the hollow part of the posterior process just described served equally well either for the lodgement of a ball of muscle or cartilage, or for the reception of the articular base of a spine, while the deep furrows above and below were for the insertion of tendons. The nearly perpendicular slant of the axis of the concavity, its shape and size, and the smoothness of its walls, strongly suggest that a dermal spine was implanted in it; but as yet we have only negative evidence of the presence of these defences in *Dinichthys*. We might theoretically associate with this genus certain detached ichthyodolulites coinciding with it in distribution throughout the same horizon; but more than a mere correspondence of parts is necessary before giving credence to such a speculation. Hence we can only affirm that if the posterior process of the dorsal shield supported a spine or spines, we are ignorant of their nature.

On the other hand, we know that the paired fins of *Dinichthys* were more or less rudimentary; and the only means for changing the direction of motion in the vertical plane while swimming was by flexure of the hinder part of the trunk and tail. It is evident that muscles inserted along the posterior process of the dorsal shield, and continued down the back on either side of the neural arches, would on contracting produce an upward flexure of the caudal region, owing to the arched curvature of the body. The effect of such a flexure is equivalent to elevating the head, and would cause the fish to ascend; conversely, a depression of the head, or flexing the tail downward, would enable the fish to sink. For so ponderous a body as *Dinichthys*, a firm attachment and support for the musculature was essential, as well as means for holding the massive plates in position; and these requirements could have been abundantly supplied by the structure of the dorsal shield, supplemented by its relation with the neural spines.

Doubtless much light can be shed on these problems by a study of the musculature in the recent Siluroids. The writer is indebted to Dr. Samuel Garman for valuable information regarding this group of fishes, and for the opportunity of dissecting an alcoholic specimen of *Loricaria* from South America. The condition of the latter, however, although showing excellent skeletal details, was unfavorable for an investigation of the muscular system.

ART. VII. — *The Tertiary Floras of the Yellowstone National Park*; by F. H. KNOWLTON, of the U. S. Geological Survey.

It has long been known that the Yellowstone National Park, in addition to its numerous interesting geological features, possesses what is probably the most remarkable fossil forest known, and an abundance of finely preserved fossil plants. The writer has been engaged, for the past year or more, in the careful study of this flora, and the present paper has been prepared for the purpose of calling attention to some of the more important geological and biological results. The full report, with descriptions of new species and illustrated by forty-five quarto-plates, will appear in a monograph of the U. S. Geological Survey.

The localities that have supplied the Tertiary flora are all located in the north-eastern part of the Park, in the vicinity of the junction of the Lamar River with the Yellowstone, and along the Lamar River for a distance of ten or twelve miles from its mouth. The first fossil plants obtained from that portion of the Park were brought back by the early Hayden Survey parties. They were submitted to Prof. Leo Lesquereux, and although few in number, the species were nevertheless sufficient to afford some indication of their age. Professor Lesquereux regarded the plants from Elk Creek and vicinity as indicating an Eocene age, and those from the well-known Fossil Forest on the west side of the Lamar Valley as closely allied to the Auriferous Gravels of California. It is a pleasure to state that this adumbration has been abundantly confirmed by the results of more searching study of a larger amount of material; but at the time Lesquereux's statement was made, the facts were so few that the suggestions were not regarded as conclusive, and as it was before careful, detailed geological work had been done, these now clearly-defined beds came to be grouped together under the somewhat non-committal term Volcanic Tertiary.

Although the geology of the region has been fully discussed by Mr. Arnold Hague in a preceding article,\* it seems necessary for a satisfactory understanding of the problems requiring solution to set forth briefly the geological features characterizing this portion of the Park which have a direct bearing upon the remarkable flora found. In the first place, all the material constituting the beds, in which the Tertiary plants are imbedded, is of volcanic origin. According to the geologists, this material may be divided into two distinct periods of volcanic eruption which can be distinguished by their mineral composition.

\* June number, p. 445.



The older series of these lavas has been designated as the early acid breccias and flows and the younger as the early basic breccias and flows. Both these series of rocks carry plant remains. In general, the matrix in which the plants are preserved is a fine-grained ash, probably deposited as a mud-flow, in places with the appearance of stratification and other indications of waterlain deposits; occasionally the material is much coarser and has the appearance of breccias mixed with fine sediments. The acid rocks are usually light in color, yellow, lavender, or gray, while the basic rocks which carry more iron are darker in color, frequently some shade of green or dark brown, passing over into black. In some instances, as might be expected with fine waterlain beds, the deposits in both series of lavas closely resemble each other, while the great mass of lava of the two bodies may be readily distinguished. The acid breccias, the oldest of the lava flows, rests in many places upon the upturned edges of Archæan and Paleozoic rocks. In most instances, the basic breccias either rest directly upon the acid rocks, or else the underlying rocks are not exposed. The acid breccias are found on both banks of the Yellowstone River, below the mouth of Elk Creek. Again, near the junction of Hell Roaring Creek with the Yellowstone River, on Crescent Hill and near the head of Tower Creek.

In the neighborhood of Lost Creek and on the northern end of Specimen Ridge, along the drainage of Crystal Creek, the basic breccias are known to lie directly upon the acid breccias. In these localities the flora has a distinct character of its own, and bears evidence of being younger than the flora from the acid breccias. The basic series of rocks is typified at the Fossil Forest and also at the cliff a short distance to the south and east of the Fossil Forest. They also occur on the east bank of the Lamar River between Cache and Calfee Creeks. All of these localities are characterized by their plant remains, and the following determinations of age seem fully warranted.

The Tertiary floras as above outlined are found to embrace 147 more or less satisfactory species. Of this number, 81 species, or over 50 per cent., have been described as new to science. With these must be placed eight forms that have not been specifically named, thus leaving 58 species that were before known, and upon which we must largely depend in the determination of the age of the various strata in which they are contained.

The study of these plants has brought out the fact that they may be naturally divided into three more or less distinct floras or stages. These divisions, as already hinted in the remarks concerning the geology of the beds containing them, correspond with the geological divisions based upon the petrographical characters of the rocks. The first or older flora from the acid

rocks embraces 79 species or forms; the second or intermediate flora has 30 species, and the third or younger flora, from the basic rocks, embraces 70 species or forms. It further appears that 23 species or forms are common to two or more of these divisions.

The flora of the older or acid series will be first considered. Of the 79 species, 42 are either new to science or not specifically named, leaving 37 species having a distribution beyond the limits of the Park. These 37 species are distributed as follows: 17, or nearly one-half, are found also in the Ft. Union beds near the mouth of the Yellowstone; 5 each are found in the coal-bearing Laramie, Denver, and Livingstone beds; 9 in the Green River Group and 10 in the Auriferous Gravels of California. Of the species found in the Laramie, Denver and Livingston beds, not one is confined to these beds and the acid rocks of the Park, but they are such species as *Sequoia Langsdorffii*, *Juglans rugosa*, *J. Schimperii*, *Platanus Guillelmae*, etc., that enjoy a wide geological and geographical distribution. The Ft. Union element in this flora is thus shown to be a very important one, and when the evident affinities of the new species are followed out, it becomes clearly the dominant element. It includes at least 12 species that have never before been found outside of the type locality. Among these are: *Sparganium stygium*, *Populus speciosa*, *Populus daphnogenoides*, *Ulmus minima*, *Ulmus rhamnifolia*, *Sapindus affinis*, *Sapindus grandifolius*, and *Cornus acuminata*. Some of these are represented by as many as two hundred individuals, showing that they existed in great abundance.

Upon this evidence the flora of the acid rocks is referred to the Ft. Union or lower Eocene.

It will be next in order to consider the intermediate flora. As already stated, this embraces 30 species, of which number 18 are regarded as new to science. Of the 12 remaining species having a distribution beyond the limits of the Park, 6 are found in the Auriferous Gravels of California. Only 2 species are common to this flora and the acid rocks below, and only 3 to the basic rocks above. The affinities of this so-called intermediate flora are not especially pronounced with either of the other series, but considering the number of species common to the Auriferous Gravels and also the affinities of the new species, it is found that the greatest similarity is with the upper series, and for these reasons this flora is regarded as Miocene but older than the Auriferous Gravels.

It now remains to consider the flora of the basic rocks and its relationships. The typical locality for this flora is the celebrated Fossil Forest and vicinity. It embraces 70 species or

forms, distributed as follows: 38 species new to science, 3 forms not specifically named, and 29 species having a distribution outside the park. Of these 29 species no less than 17 are found to be common to the Auriferous Gravels of California. These are such important and easily recognized species as *Aralia Whitneyi*, *Persea pseudo-Carolinensis*, *Laurus Californica*, *L. grandis*, *Magnolia Californica*, *Ficus sordida*, *Juglans Californica*, *Rhus mixta*, etc.

Besides the species above enumerated that have actually been found common to the two localities, the numerous new species are unmistakably related to species only known from the Auriferous Gravels. Thus one of the new magnolias is closely allied to *M. Californica*, and another is so close to *M. lanceolata* that it was so identified by Professor Lesquerenx.

Other examples might be given but they are unnecessary in the present instance. The preponderance of evidence points to the similarity of age between the flora of the basic rocks and that of the Auriferous Gravels of California. In order to further characterize it, it may be called the Lamar flora from the river and valley along which the principal exposures occur. The age is regarded as upper Miocene.

When viewed from the biological side this Tertiary flora is found to present many interesting features. It is a rich flora, and on comparing it with the living flora it becomes apparent that great climatic changes must have taken place since the close of the Miocene period, to have made possible these changes in plant life. The fossil flora, as already stated, embraces 147 forms, that are distributed among 33 natural orders. Following is a list of these orders with the number of species or forms referred to each:

|                          |   |
|--------------------------|---|
| <i>Filices</i> 10.       | * <i>Lauraceæ</i> 11.                     |
| <i>Equisetaceæ</i> 4.    | * <i>Platanaceæ</i> 3.                    |
| <i>Coniferæ</i> 13.      | <i>Leguminosæ</i> 5.                      |
| <i>Typhaceæ</i> 1.       | * <i>Anacardiaceæ</i> 1.                  |
| * <i>Sparganiaceæ</i> 1. | * <i>Celastraceæ</i> 4.                   |
| <i>Cyperaceæ</i> 4.      | <i>Aceraceæ</i> 2.                        |
| <i>Smilaceæ</i> 1.       | * <i>Sapindaceæ</i> 5.                    |
| <i>Musaceæ</i> 1.        | <i>Rhamnaceæ</i> 3.                       |
| * <i>Juglandaceæ</i> 8.  | * <i>Vitaceæ</i> 1.                       |
| * <i>Myricaceæ</i> 3.    | * <i>Sterculiaceæ</i> 1.                  |
| <i>Salicaceæ</i> 11.     | * <i>Credneriaceæ</i> 1.                  |
| <i>Betulaceæ</i> 2.      | * <i>Tiliaceæ</i> , 2.                    |
| * <i>Fagaceæ</i> 15.     | * <i>Araliaceæ</i> 6.                     |
| * <i>Ulmaceæ</i> 5.      | <i>Cornaceæ</i> 2.                        |
| <i>Urticaceæ</i> 10.     | <i>Ericaceæ</i> 1.                        |
| * <i>Magnoliaceæ</i> 5.  | * <i>Ebenaceæ</i> 3.                      |
|                          | * <i>Oleaceæ</i> 1.                       |
|                          | * <i>Phyllites</i> , * <i>Carpites</i> 3. |



The excellent *Flora of the Yellowstone National Park*\* by Mr. Frank Tweedy has been made the basis of all comparisons between the fossil and living floras. According to Tweedy the present flora embraces 69 natural orders, 273 genera and 657 species. The fossil flora embraces 33 orders, 63 genera, and 147 species. The living flora has therefore 4 genera to each order and 2.4 species to each genus, while the fossil flora has not quite 2 genera to each order and 2.3 species to each genus. The relative proportion between the orders, genera and species is shown to be approximately the same in the living and Tertiary floras. A still further comparison shows that there are a fraction more than twice as many living as fossil orders, 4.3 times as many living genera and 4.6 times as many species.

On comparing the orders in the two floras it is found that 19 of the 33 fossil orders are not represented in the living flora.† It is found that such important orders as the Juglandaceæ, Fagaceæ, Ulmaceæ, Magnoliaceæ, Lauraceæ, Platanaceæ, Anacardiaceæ, Celastraceæ, Vitaceæ, Sterculiaceæ, Tiliaceæ, Araliaceæ, Ebenaceæ, and Oleaceæ, are not represented in the present flora. In other words there are no walnuts, hickories, oaks, beeches, chestnuts, elms, magnolias, sycamores, sumacs, grapes, lindens, azalias, persimmons, or ashes at the present day.

The dominant elements in the living flora are the abundant coniferous forests, yet only eight species are present and of these only five are at all common, and 65 per cent. of the whole coniferous growth is made up of one species (*Pinus Murrayana*). The fossil flora is represented by thirteen species, or nearly twice as many as the living. Among them was a magnificent *Sequoia* that was closely allied to the living *Sequoia sempervirens* of the Pacific coast. It had trunks ten feet in diameter, and there are indications that they were of great height. There were also two well-marked species of *Sequoia* known from the leaves and a number of supposed *Sequoia* cones. The pines were in abundance, no less than seven species having been detected. Of these two are known from the leaves, three from beautifully preserved cones and two from the internal structure of the trunks.

The living deciduous-leaved trees and shrubs of the Yellowstone Park are conspicuously few in number. There are two species of *Betula*, two of *Alnus*, seven of *Salix*, two of *Populus*, one of *Acer*, four of *Vaccinium*, five of the order *Caprifoliaceæ*, two of *Cornaceæ*, two of *Rosaceæ*, etc. Perhaps the most conspicuous tree is the quaking aspen (*Populus tremu-*

\* Wash., 1886, pp. 1-78.

† In the list of orders given above those not represented at the present day are marked with an asterisk.

*loides*). The cotton wood (*P. angustifolia*) is rare, being found in only one locality, according to Tweedy. Several of the willows are abundant, as is also the common birch of the region (*Betula glandulosa*), and the June-berry (*Amelanchier alnifolia*). The other shrubs are either rare or confined to few localities.

The fossil flora, on the other hand, was especially rich in deciduous-leaved vegetation. Thus the Juglandaceæ was represented by five species of Juglans and four species of Hicoria (*Carya*), a number of which were very abundant.

The genus *Populus* was particularly rich, there being no less than seven species. Certain of these, as *Populus speciosa*, *P. glandulifera*, and *P. daphnogenoides*, were in great abundance, and the stratum in which they occur consists of a perfect mat of these leaves. Something over one hundred examples of one of these species were obtained.

Another striking feature was the presence of numerous magnificent *Magnolias*; of these four species have been described from the leaves and one from the thick petals of the flower. One of the new species, represented by a great number of leaves in a fine state of preservation, appears to be more closely allied to the living *M. fatida* (*M. grandifolia*) than any previously described.

The sycamores were also an important element in this flora. Of the two species described from the leaves and one from the wood, the one known as *Platanus Guillelmae* was especially abundant. It is found in nearly all of the Tertiary beds in the Park, and is represented by nearly two hundred examples. The species described from the wood is based upon a trunk about one foot in diameter and is most closely allied to the living *P. occidentalis*.

Another important group is formed by four species of *Aralia*. Of these *Aralia notata* was evidently the most abundant and imposing plant of the whole flora. The collections contain over one hundred specimens. None of them are preserved entire, but there is abundant evidence to show that some of these leaves must have been fully three feet in length and more than two feet in width. *Aralia Whitneyi*, a species common to the Auriferous Gravels of California, had striking five to seven-lobed leaves often one foot in length. This species was not as abundant, judging from the fossil remains, as the former species, but it was apparently quite widely distributed. The other species had smaller three or five-lobed leaves.

The Lauraceæ was strongly represented by five genera, eleven species, and a large number of examples. The genus *Laurus*, which is now exclusively an old world form, was represented by six well-marked species. The genera *Litsea* and

Cinnamomum, other old world forms, were both represented, the former by two and the latter by one species. The genus *Persea* was also represented by a single species.

Another large and important group, now entirely unrepresented in the Park, is the Fagaceæ, embracing two species of *Fagus*, one of *Castanea*, eleven of *Quercus* and one of *Dryophyllum*. The *Fagus* described as new is a beautiful characteristic leaf, evidently rare, as it is found in only one place. The *Castanea*, on the other hand, was very abundant and widely distributed within the Park. The leaves are large and as handsome and striking as are the leaves of the common living species (*C. dentata*). The oaks, however, were abundant in species and usually in individuals. They are all but three new to science.

The Urticaceæ, which are represented in the living flora by a single rare herb (*Urtica gracilis*), was represented during Tertiary times by some ten species of *Ficus* and a single more or less doubtful species of *Artocarpus*. Only two or three species of *Ficus* were particularly abundant, at least as evidenced by their fossil remains. It is of great interest to learn, however, that they were once present in a region that has long since ceased to support them. The curious leaf referred provisionally to *Artocarpus* is also of much interest as indicating the possible presence of the bread-fruit tree in this portion of the American continent. Two unmistakable species of *Artocarpus* have already been detected; one from the Laramie and Denver beds of Colorado, and the other from the Auriferous Gravels of California and the Miocene of Oregon.\*

It is therefore not improbable that the type was in existence in the Yellowstone Park during the early Tertiary.

The Leguminosæ, now represented by a host of small herbaceous plants, was then represented by three species of *Acacia*, known from pods, and two of Leguminosites, known from leaflets. But none of them is particularly satisfactory.

The only remaining group of deciduous-leaved plants of any magnitude is the Sapindaceæ with five species of *Sapindus*. Of these *Sapindus affinis* is perhaps the most abundant form found among the Tertiary plants of the Park. The small characteristic leaflets are found in the greatest profusion. The other species were less abundant.

The other forms that require mention are *Ulmus* with four species, *Acer* with at least two species, *Celastrus* with three species and *Rhamnus*, *Paliurus*, *Zizyphus*, *Cissus*, *Pterospermites*, *Tilia* and *Rhus* with a single species each.

\* Science, vol. xxi, p. 24, 1893



The cryptogams appear to have been a much more prominent floral feature during Tertiary times than now. Of the two orders present, the Filices and Equisetaceæ, the former is represented by ten and the latter by four species, while the living flora has but six ferns and four horsetails, all of which are rare.

The ferns were abundant. They belong to six genera and are represented in several cases by a large number of specimens. The largest genus is *Asplenium* with four species. One of these that has been described as new is perhaps the largest and finest that has been detected outside of the Carboniferous, at least in North America. The genus *Aspidium* is represented by two species, both of which appear to have been rare. They are, however, both fruiting, a condition of uncommon occurrence among fossil forms. There is also a fine *Woodwardia* that appears to be quite closely allied to a species now living in the eastern United States, and beautifully preserved examples of the widely distributed climbing fern (*Lygodium Kaulfussii*). It is very similar to the only living North American species *L. palmatum*. The other ferns are an *Osmunda* and a delicate form referred provisionally to the genus *Davallia*.

The genus *Equisetum*, although represented by four more or less satisfactory species, was not abundant or particularly important. The commonest form is small and has much the appearance of the living *E. limosum*.

From what has been presented, it is obvious that the present flora of the Yellowstone National Park has comparatively little relation with the Tertiary floras, and can not be considered as the descendant of it. It is also clear that the climatic conditions must have greatly changed. The Tertiary flora appears to have originated, or at least to have had its affinities at the south, while the present flora is evidently of northern origin. The climate during Tertiary time, as made out by the vegetation, was *apparently* not unlike that in some parts of the southern United States at the present day.

It would be of interest to describe the remarkable fossil forests of standing trunks, but their consideration must be deferred to the final report.

ART. VIII.—*A New Belodont Reptile* (STEGOMUS) *from the Connecticut River Sandstone*; by O. C. MARSH. (With Plate I.)

THE red sandstone of the Connecticut valley has long been famous for its footprints, especially the so-called "bird tracks," which are now very generally believed to have been made by Dinosaurian reptiles. These strata, however, like most deposits of similar physical character in other parts of the world, contain few osseous remains, and those discovered here, almost without exception, belong to carnivorous Dinosaurs of Triassic types, as the writer has shown elsewhere.

The *Belodontia*, one of the most characteristic groups of Triassic reptiles, are almost unknown in the Connecticut river sandstone, a single specimen only having been discovered, and recently named by the writer *Belodon validus*.\* No footprints that can be referred to this order of reptiles have yet been found among the thousands brought to light in this region, although a careful search for such impressions has long been maintained, especially in the horizons where they were most likely to be preserved.

During the past year, a noteworthy discovery has been made in the Connecticut sandstone, within the city limits of New Haven, and it is the main object of the present paper to place this discovery on record, both on account of its local interest and its scientific importance. The specimen found is represented in the accompanying plate, one-third natural size. The fossil shows the impression of the dermal armor of a large reptile, which apparently represents a new genus of the *Belodontia*. The dermal covering thus preserved is mainly from the dorsal region, although the anterior part protected the back of the neck. No other portions of the dermal armor nor any of the skeleton were found, although a careful search was made at the time of the discovery and subsequently, both at the locality itself and in the vicinity. It is therefore probable that the dermal covering here described was torn from the animal after death and before entombment in the coarse sand and gravel then deposited by a strong current, as indicated by the present structure of the sandstone.

In the fossil represented in the accompanying plate, the dorsal region of the reptile is shown, with the anterior portion to the left. The median dorsal line is indicated by the narrow longitudinal ridge, placed nearly horizontal in the figure. In the cervical region, this nearly straight line is broken,

as the armor was here turned slightly to the right and somewhat twisted. This median ridge was formed by the matrix filling the narrow space between the ends of the dorsal plates, where they met in pairs on the median line. The transverse ridges are likewise due to the filling in of the matrix between the adjoining plates, which evidently were somewhat separated by connecting tissue admitting of more or less motion, but which held the whole dorsal armor together as a carapace.

The large median plates indicated in this fossil are twenty in number in each of the two rows meeting on the middle line. These plates are elongated transversely, strongly convex, and their form is accurately shown in the figure. Their inner extremities are nearly at right angles to the sides, but the outer ends are oblique where they join the plates of the lateral series, or second row. These lateral plates were quite short, and their form and position are clearly preserved in the specimen figured. All the dermal armor indicated resembles, in its general features, the corresponding portions in the genus *Aëtosaurus*, Fraas, from the upper Trias of Germany. In the latter, however, the plates are imbricate.

The above description is based upon the impressions left by the inferior side of the plates upon the plastic matrix in which they were imbedded. The plates themselves have since disappeared, having been dissolved by infiltrating waters. The cast of the superior surface of the plates was of somewhat softer material than the matrix below, and most of it was lost in removing the specimen. The portions recovered show that the upper surface of the plates was rugose, but not deeply sculptured, being less marked in this respect than in the other known species of Belodonts. The rough surface preserved shows no regular pattern of ornamentation, and there are no indications of a crest on the plates. The form and position of the plates are characteristic features, and as both the genus and species appear to be distinct, the reptile may be known as *Stegomus arcuatus*. The animal when alive was of moderate size, probably eight or ten feet long. This would be about two-thirds the size of *Belodon validus*, the scapula of which is eight and one-half inches in length. The fossil here described indicates an animal with a body capable of some lateral flexure and considerable vertical movement. The type specimen was found by F. P. Clark, and presented by D. A. Van Hise to the Yale University museum.

Outside the Connecticut valley, remains of *Belodontia* have been found at several points in this country. Some of the best known were discovered by Prof. Emmons in the Triassic of North Carolina, most of the specimens having been obtained in the Deep river coal mines. One of these fossils is the skull figured by him under the name *Rutiodon Carolinensis*.\*

\* Manual of Geology, p. 179, 1860.



The genus is a distinct one, the characters now known separating it widely from *Belodon* of von Meyer, from the Keuper of Würtemberg. This is indicated in figures 2 and 3, below.

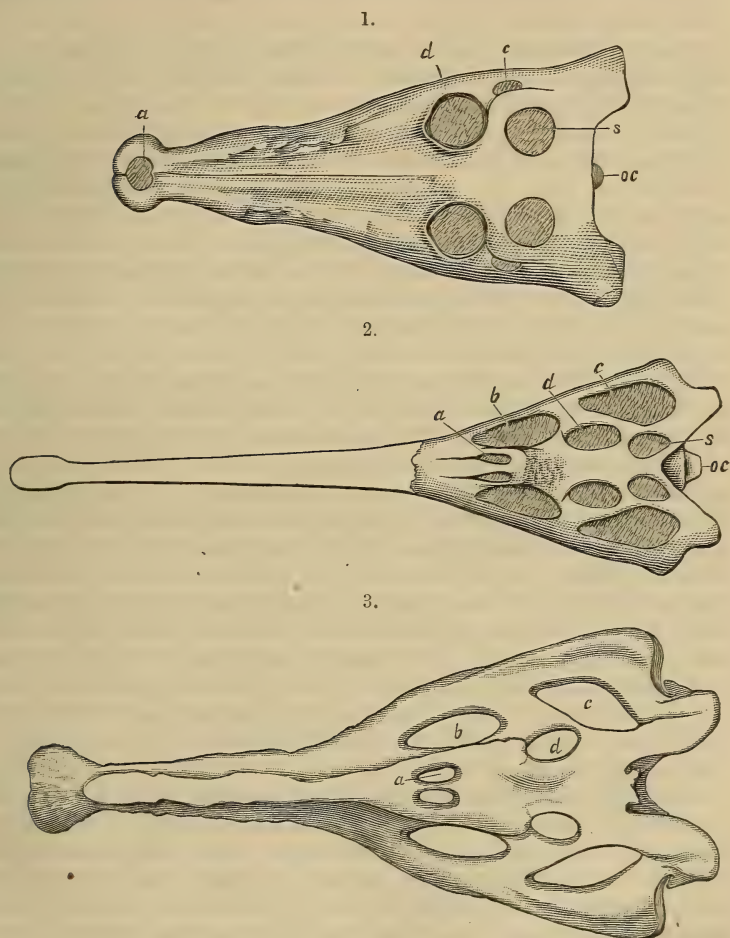


FIGURE 1.—Diagram of skull of *Diplosaurus felix*, Marsh.

FIGURE 2.—Diagram of skull of *Rhytidodon rostratus*, Marsh.

FIGURE 3.—Diagram of skull of *Belodon Kapffi*, von Meyer.

*a*, nasal aperture; *b*, antorbital opening; *c*, infratemporal fossa; *d*, orbit; *oc*, occipital condyle; *s*, supratemporal fossa.

Figure 1 is one-fourth, and figures 2 and 3 are one-eighth natural size.

The diagram of the skull of *Belodon* shows that the supratemporal openings, characteristic of the true crocodilians, are wanting, while in the genus *Rhytidodon* (*Rutiodon*), they are present, and in their usual position. The fluted teeth of

the latter genus are different from those of *Belodon*. Figure 1 shows the skull of *Diplosaurus*, a crocodilian from the Jurassic of Colorado. The superior nasal aperture (*a*) is in front, as in existing crocodiles, while in the Belodonts, as shown in figures 2 and 3, these openings are far back in the upper part of the skull. Figure 2 represents a new species, found by J. B. Hatcher in the Triassic of North Carolina. In this specimen, the quadrate slopes forward, and not backward as in the *Crocodylia*.

Other fossils of apparently the same group have been found in Pennsylvania, and described by Lea under the generic name *Centemodon*, and by Leidy, as *Omosaurus*. Still others were described later by Cope, from both Pennsylvania and North Carolina, and more recently some from the Triassic of New Mexico, which received the names *Typothorax* and *Episcoposaurus*. Nearly all the above specimens are so fragmentary that it is at present difficult, if not impossible, to determine their exact relations to each other.

The difficulty in this case is practically the same as that which has occurred time and again in separating fossils found together at other localities, especially where genera of reptiles have been based upon isolated teeth, which, unlike those of mammals, have so often proved unreliable. In the original locality of *Belodon*, near Stuttgart, in Germany, remains of carnivorous Dinosaurs (*Zanclodon*) also occur, while Labyrinthodonts are still more abundant, all represented by species of approximately the same size. The fragmentary remains of these, when mixed together, have led to much confusion, as the many names proposed for them demonstrate. After various well-preserved specimens were studied, the separation of the Labyrinthodonts, even in isolated remains, became a comparatively easy matter, but the Belodonts and Dinosaurs, being more nearly allied, have hardly yet found their proper places.

Precisely the same thing occurred when the rich North Carolina localities of nearly the same horizon were first explored. The Belodonts, Dinosaurs, and Labyrinthodonts were all there, with their fragmentary remains commingled in a still more indiscriminate manner. This was in part true, also, of the Pennsylvania localities, and those in New Mexico have likewise contributed their share to the general confusion. The discovery of more perfect specimens will doubtless gradually remove the obscurity now existing as to the strange vertebrate fauna of this extensive horizon.

Yale University, New Haven, Conn., June 5, 1896.

#### EXPLANATION OF PLATE I.

Impression of dermal armor of *Stegomus arcuatus*, Marsh. One-third natural size. From the Triassic sandstone, New Haven, Conn.

ART. IX.—*On Separation, and its bearing on Geology and Zoögeography*; by ARNOLD E. ORTMANN.

IN a recent publication\* I pointed out the importance of the principle of *separation* or *isolation* as regards the distribution of animals as well as the origin of species. The present article intends to give a short review of the views set forth in the book referred to, especially regarding the geological and palæontological aspect of the matter.

While some authors believe that *natural selection* is sufficient for the explanation of the origin of species, and that "the mode of formation of the living world as a whole" (Weismann) can be understood by his principle, I maintain, on the contrary, that natural selection is only one of the factors coöperating in the formation of species, and especially, that it acts only in a particular line, namely effecting a slow transformation of existing species. In the book referred to (p. 31) I have shown that by natural selection only a transformation of one already existing species into one other species is possible, but that it is impossible to think that two or more different species originate from one original species by selection. The transformation of species in time is entirely different from the differentiation into several contemporaneous species. The former process, well known to palæontologists under the term "mutation" (Waagen, Neumayr, Scott) has been generally not properly understood by biologists, and I cannot enough emphasize, that mutation of one species in time should not be confounded with differentiation into coexisting species.

As I have demonstrated (l. c., p. 31), the latter process is due to the factor called by M. Wagner separation or isolation, and although this principle has been discussed by many subsequent authors, it has been—with few exceptions (G. Baur)—generally misunderstood or not accorded its full value, since most authors have conceived it only in a purely geographical sense. Yet in nature we have not only a purely geographical separation, but many other causes may have the same effect. Generally we may say, that any causes which induce certain groups of animals to live under particular conditions of existence, while other related groups are not subject to the same conditions, in other words, that any causes effecting a permanent interruption of the bionomical continuity between certain groups, come under the head of the term separation. Separation keeps particular groups permanently under particular conditions, and

\* Grundzüge der marinen Tiergeographie, Jena, 1896.



thus they are prevented from migrating from one station of definite conditions of life into others with other conditions.

Separation has acted since the beginning of the geological history of organic beings upon their differentiation into species. In the most remote geological periods we can distinguish particular parts having each different conditions of existence. The most general differentiation is created by the existence of particular life-districts:\* districts of different primary conditions of life. The chief differences (l. c., p. 18) are made up of the conditions of the light, medium, and substratum, and according to the different features of these three conditions I have distinguished as follows:

1. Light. The medium is air. Substratum present.—Terrestrial district.

2. Light. The medium is fresh water. Substratum present.—Fluvial district.

3. Light. The medium is salt water. Substratum present.—Littoral district.

4. Light. The medium is salt water. Substratum wanting.—Pelagic district.

5. Dark. The medium is salt water. Substratum present.—Abyssal district.

These are practically the most important life-districts, and, as a rule, every form of animal life is restricted to one of them. But there are a few exceptions, that is to say, sometimes certain animals migrate from one district into another: such changes, however, are regular ones, and are governed by strict laws. Any artificial or unnatural transplantation of a species from the proper life-district into another involves the impossibility of its farther existence.

Life-districts have existed since dry land rose above the surface of the ocean. It is generally accepted, that first an ocean of an equal (but considerable) depth covered the whole surface of the lithosphere, and subsequently, by the subsidence of certain parts of the latter, and by the compensating upheaval† of other parts of the earth's crust, greater depths of the ocean were formed, and parts of the lithosphere rose above the sea-level. As soon as this was accomplished, the five different life-districts were present. I have shown further (l. c., p. 39), that the topographical continuity of each of these life-districts is different, and especially, that during the geological development of the earth the external limits of each changed in a considerable degree (l. c., p. 64): continuous parts were separated, and separated parts connected. These changes are most conspicuous and important in the terrestrial, fluvial, and littoral

\* "Lebensbezirke," see l. c., p. 15.

† I differ in this respect from Süss' opinion.

districts, while the pelagic and abyssal maintained during all the geological part their continuity, and are still at present perfectly continuous topographically. This continuous change, especially within the littoral district, during the different geological periods is very remarkable. No doubt, these changes take a considerable part in developing a great diversity of species.

But not only the differences of the life-districts and their topographical features effect separation of the inhabitants, but within each life-district, independently from the topographical continuity, separate parts are present. I refer to the differences of what is called facies (l. c., p. 23). Although the differences of facies are first recognized by geological science, and although it is well known that the living as well as the fossil organisms are influenced in a considerable degree by the facies, and are adapted to and dependent on particular facies, this factor, I think, is not yet considered properly in palæontology. In papers discussing the different faunas of the same geological period, differences of the fossil remains found in strata of apparently the same age, are often attributed to separation of the respective sea-basins by land,\* as the only means producing a different development of species in the seas thus separated: but separation by differences of facies may induce the same process. Palæontologically and geologically, it is a well known fact, that certain groups of animals prefer particular facies, but we have no definite proof yet, that different but nearly allied species are found in different facies, and in most cases we do not, or only incompletely, know the particular conditions under which the different beds were deposited.

We see often that in the geological succession one facies is replaced by another, and very often we see that the imbedded fauna becomes entirely different accordingly. In other cases, however, we have in an overlying bed apparently the transformed descendants of the underlying fauna, and lastly, I wish to direct attention to a fact, which appears at first strange, namely the reappearance of an older fauna in younger strata.† It may be possible that such cases are due to a change of facies: the original facies and its peculiar fauna are replaced in a particular locality by another facies with its fauna, but later on the first occupied this locality again, and the old fauna reappeared.

\* I refer for example to a recent paper of Weller: A circum-insular Palæozoic fauna.—*Journ. Geolog.*, Chicago, iii, 8, 1895, p. 903-927. I do not wish to criticise this very important article as regards the results obtained, but only to suggest, that the differences of facies certainly present in the localities discussed should be considered also.

† Compare Barrande's "colonies" in the Silurian strata of Bohemia, and H. S. Williams' paper entitled: The recurrence of Devonian fossils in strata of Carboniferous age, this *Journal*, xlix, 1895.

It is obvious that in this respect there is an ample field of research left unoccupied. Although the geological development of many groups of fossil animals in the successive strata has been investigated, no attention is directed to the influence of the conditions of life upon the single forms, and the influence of separation of these conditions upon the differentiation of particular directions of development. The extant investigations treat the matter from a mere systematic and phylogenetic standpoint, referring only to the stratigraphical conditions, but the facts of geographical distribution, and especially of bionomic relations, that is to say, the relations to the general conditions of life, are mostly neglected. Of course, such studies as are desired here are very difficult, especially because the exact synchrony of the zoölogical facies deposited in different localities is often uncertain; but it would be very desirable to collect carefully all the facts relating to these questions, in order to secure material for a study of the mutual relations of the different facies in time and space. Thus, I hope, it will be possible, not only to trace particular species in their development through different zones, but to understand their successive mutations and differentiations into separate species, at least within smaller periods of the geological history of the earth, and the study of palaeontology may demonstrate, that separation is a continuously acting factor in the formation of species, and may support my opinion, that it is that particular factor which causes the differentiation of species.

In more recent geological times another factor causing separation is added: the climatic differentiation of the surface of the earth. I have demonstrated (l. c., p. 40) that this factor most especially effected the breaking up of the old and more or less continuous life-districts into zoögeographical provinces. While the terrestrial and fluvial districts have been characterized since the beginning of their existence by discontinuity, the continuity of the marine districts has been interrupted in a peculiarly complicated manner since the introduction of climatic changes, which began in the earliest Tertiary period.† For zoögeographical studies I have divided (l. c., p. 45–60) those parts of the earth which are occupied by the oceans into the following regions:

I. Littoral life-district.

1. Arctic region.    2. Indo-Pacific region.    3. West American region.    4. East American region.    5. West African region.    6. Antarctic region.

\* In a paper published recently (this Journal, April, 1896) I have demonstrated, that Neumayr's theory of the existence of climatic zones in Jurassic times is without a proper foundation. I may add here, that the same opinion (that climatic changes did not begin until the Tertiary time) is set forth recently by Dubois (The climates of the geological past, 1895).



## II. Pelagic life-district.

1. Arctic region. 2. Indo-Pacific region. 3. Atlantic region. 4. Antarctic region.

## III. Abyssal life-district.

No regions distinguishable.

It is very remarkable that it is impossible to distinguish any regions in the abyssal district. As this whole district is characterized by a low and very nearly constant temperature, no climatic zones can be distinguished, and further, as this whole district is continuous throughout its extension over the bottom of the oceans, no topographical divisions are present. Therefore we cannot establish any zoögeographical regions within this district, which agrees with the well-known fact that most of the true abyssal animals have a world-wide distribution.

But even in the Tertiary period the limits of the zoögeographical regions of the littoral and the pelagic districts were often very different from those of the recent time, because the topographical features of the seas were different. As the most important difference should be regarded the continuity of the circumtropical belt maintained during a great part of the Tertiary. This continuity was due to the well-known fact, that the connection of North and South America was not yet formed, and, perhaps, that there was present a communication of the southern European seas with the Indian Ocean. The separation of the Mediterranean Sea from the Red Sea and the Indian Ocean, and its connection with the Atlantic Ocean, and especially the separation of the Pacific Ocean from the West Indian seas by the rising of the Isthmus of Panama, were the last steps accomplishing the development of the recent conditions, and the latter are, geologically speaking, of a very recent date: they were not formed until the second half of the Tertiary period.

It is very interesting, that the present geographical distribution of many animals points often and clearly to the former conditions existing a comparatively short time ago, and the geographical distribution, if regarded under the principle, that species are formed by separation, may give us some hints as respects the former geological and geographical conditions. It may be well here to indicate some principles worthy of notice.\*

\*I have myself endeavored to apply the following principles in a series of monographs discussing the distribution of smaller groups of Decapod-Crustaceans. As regards the influence of external conditions, climate, facies, etc., upon the distribution of species in a particular locality, I should like to refer to a most valuable work published by Petersen (Det Videnskabelige Udbytte af Kanonbaaden "Hauchs" Togter, 1893, p. 433-464). It would be very advantageous for science if investigations of this kind were made more extensively.

1. Each species must have originated in a separate locality (center of origin).

2. It is very improbable that the same species originated twice in different and separated parts of the earth.

3. The same species existing in completely separated localities indicates a former connection, which, as a rule, lies not far back in time.

4. Nearly allied species in separated localities indicate a former connection, but in a more remote time. The degree of relation may give a rough estimate of the relative time that has elapsed since separation.

5. Formerly separated parts of the earth's surface are difficult to locate, since a later connection destroys the differences that existed formerly, and the animals peculiar to each separate part cannot be recognized.

I may add, that palæontological research may find out, and indeed in some cases has already found out, examples of the latter kind,\* since the peculiar fauna of an isolated locality can be preserved in fossil state.

I think I have sufficiently demonstrated, that the principle of separation not limited to a strictly geographic sense, but enlarged, and understood generally as a bionomic principle, is not only important as regards the origin of species, but also as regards geographical distribution, palæontological and geological history of animals. Bionomic separation means that it is essential for separation, that the groups of animals separated from each other are subject to different conditions of life, and I emphasize this point as the chief peculiarity which effects a differentiation of the characters of animals inhabiting different stations. We can imagine a purely geographical (topographical) separation with the conditions of existence remaining unaltered in the separated parts: then a differentiation of species does not result, and the original species continues to exist without a change. We know many examples of this kind, that an identical species is found in separate localities, and I have called (l. c., p. 34) such species relics from a former continuous distribution.

I think, everybody who has ever undertaken to study the origin of species will agree with the views set forth here, at least as regards the insufficiency of natural selection for the differentiation of species, and everybody will concede, that *transformation or mutation* of a species is fundamentally different from differentiation into coexisting species, and that in this respect Weismann's opinion, that natural selection may explain "the mode of formation of the living world as a

\* For example: Neumayr in the Cretaceous and Jurassic periods, Mojsisovics in the Triassic, and recently Weller in the Devonian period.

whole," is utterly unwarranted. Natural selection can never explain the divergence of the directions of mutation, that is to say, the origin of separate forms from one ancestral form: this is only conceivable if we introduce the principle of separation. But further it will be remarked, that I lay much stress upon the transforming power of the external conditions of life, and that I differ also in this respect from the theories propounded by Weismann, who does not believe, that external conditions are able to affect the body of organic forms so that the changes thus produced may be transmitted to descendants and give origin to a change of the specific characters. In this respect I may mention here, that I am a decided opponent to Weismann's theories as a whole, and that I consider them to be illogical and contrary to the known facts, which is—in my opinion—amply demonstrated already by Pfeffer and O. Hertwig. I refer only to these critics among the large number of Weismann's adversaries, especially since Pfeffer\* has engaged himself in demonstrating the logical contradictions of Weismann, and O. Hertwig† in demonstrating the contradictions of Weismann's theories to the facts. Perhaps, I shall find opportunity to contribute to the criticism of Weismann's theories elsewhere: it may be sufficient here to say, that I cannot accept Weismann's theories of the origin of variations, and accordingly, that I must stick up for the old "working hypothesis," that variations are produced by the surrounding conditions, and that these variations may be transmitted.

Princeton, N. J., March, 1896.

\*Die inneren Fehler der Weismannschen Keimplasma-Theorie.—Verhandl. Naturwiss. Ver. Hamburg (3) I. 1894.

†Zeit- und Streitfragen der Biologie., Heft 1, Präformation oder Epigenese, Jena, 1894.



ART. X.—*An Iodometric Method for the Determination of Carbon Dioxide*; by I. K. PHELPS.

[Contributions from the Kent Chemical Laboratory of Yale University.—LI.]

IN a recent paper from this laboratory,\* it has been shown that carbon dioxide may be estimated with accuracy by absorbing it under prescribed conditions in barium hydroxide, washing away the excess of the hydroxide, and converting the precipitated carbonate to the form of the sulphate. The chief difficulty in the process was occasioned by the fact that the barium carbonate precipitated from cold solutions is so finely divided and non-crystalline in character, that the removal of the excess of the hydroxide by filtration is a somewhat delicate and tedious process. The possibility of taking up by iodine the excess of the hydroxide remaining after the precipitation of the carbonate, and then determining the excess of iodine volumetrically, furnished the incentive to the following experiments.

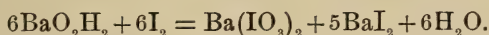
The process, as finally developed, consists of three steps: first, the evolution of the carbon dioxide and its collection in barium hydroxide contained in a partially evacuated flask; secondly, the conversion of the excess of the hydroxide to the form of iodide and iodate by adding an excess of iodine; and thirdly, the titration of the excess of iodine with standard arsenious acid.

The barium hydroxide solution was prepared for use by filtering a cold, saturated solution into a large bottle, from which it was drawn, or pumped by means of the little improvised pump described by Kreider;† in either event care was taken to feed the air, which took the place in the bottle of the hydroxide removed, through potash bulbs to prevent the introduction of atmospheric carbon dioxide. The solution of barium hydroxide was standardized by drawing 80—90 cm.<sup>3</sup> of decinormal iodine into a glass flask, provided with a ground-glass stopper carrying an inlet tube reaching nearly to the bottom of the flask and an outlet tube to which was sealed a Will and Varrentrapp absorption apparatus, and then introducing an appropriate amount of the barium hydroxide solution either from a burette or from a stoppered funnel which was weighed before and after. An ether wash bottle answers admirably for a standardizing flask, and with the glass stopper and its attachments replaced by a rubber stopper,

\* This Journal, 1, 101.

† Ibid., 1, 132.

answers the purpose of the absorption flask described later. The glass stopper is introduced, the inlet being closed by a rubber cap, and the absorption apparatus is charged with a solution of potassium iodide, to hinder the escape of iodine. The solution was brought to a boil, then cooled and the excess of iodine determined by decinormal arsenious acid. It is assumed that the iodine lost acted on barium hydroxide according to the equation:



It was found necessary to boil the solution because of the formation of traces of the hypoiodite, which is broken up into iodide and iodate only by boiling, but which, if left unchanged, acts subsequently on the arsenious acid used in titrating the free iodine.

The apparatus which I have found most convenient for evolving the carbon dioxide from the carbonate consisted of a wide-mouthed flask of about 75 cm.<sup>3</sup> capacity, furnished with a doubly perforated stopper carrying a separating funnel for the introduction of acid into the flask, and a tube of 0.7 cm. internal diameter, which is expanded to a small bulb just above the stopper, to carry off the gas. This exit tube was joined by a rubber connector to a tube which passed through the rubber stopper, closing the absorption flask (the ether wash bottle used in standardizing the barium hydroxide solution described above), and which ended in a valve preferably of the Kreider pattern.\* This valve was enclosed in a larger tube reaching nearly to the bottom of the absorption flask. Through a second hole in the stopper of the absorption flask passed a glass tube closed by a rubber connector and screw pinch cock.

In making a determination of carbon dioxide, the carbonate was introduced in weighed portions into the boiling flask. Barium hydroxide solution, in amount from 7—10 cm.<sup>3</sup> more than actually necessary to precipitate the carbon dioxide, was drawn into the absorption flask, which was then connected with the boiling flask, as described above. The stop-cock of the separating funnel was shut off and the flasks evacuated by connecting the exit tube of the absorption flask with a filter flask previously pumped out by the water pump, a mercury manometer registering the pressure. Exhaustion to a pressure of from 250–300 mm. was found sufficient and easily attainable with the available water pressure in a minute's time. Sufficient phosphoric acid (chosen as a non-volatile acid) to dissolve the carbonate was introduced into the stoppered funnel with about

\* Loc. cit.

50 cm.<sup>3</sup> of water, which had been previously purified from carbon dioxide by boiling until one-third had been driven off in steam, and kept in full, stoppered flasks until used. The acid was then allowed to enter the boiling flask and the carbon dioxide driven over completely to the absorption flask by boiling for five minutes—the latter being shaken frequently during the passage of the gas into it and kept cool by standing in a dish of water. The atmospheric pressure was then restored by admitting purified air through the funnel of the boiling flask. In the experiments of Table I, the inlet tube of the absorption flask was closed by a rubber cap after disconnection, the exit tube was attached to potash bulbs and the flask was cooled in a stream of water. The exit tube was removed, a capillary tube long enough to reach below the surface of the liquid introduced and decinormal iodine run in until the large excess of barium hydroxide had been destroyed. Then the glass stopper of the absorption flask was introduced, with a rubber cap on the inlet tube and potassium iodide solution in the trap, as in standardizing, and the emulsion brought to a boil. Iodine was again run into the hot solution through the inlet tube until the color remained distinctly red after a second boiling. After cooling, the excess of iodine was determined by standard arsenious acid.

TABLE I.

|    | CaCO <sub>3</sub><br>taken<br>gram. | BaO <sub>2</sub> H <sub>2</sub><br>taken<br>gram. | BaO <sub>2</sub> H <sub>2</sub><br>found<br>gram. | CO <sub>2</sub><br>found<br>gram. | Error<br>on CO <sub>2</sub><br>gram. | Error<br>Corrected<br>gram. |
|----|-------------------------------------|---|---|-----------------------------------|--------------------------------------|-----------------------------|
| 1  | ·0501                               | ·2484   | ·1604   | ·0227                             | ·0006 +                              | ·0007 +                     |
| 2  | ·0500                               | ·2381   | ·1508   | ·0224                             | ·0004 +                              | ·0005 +                     |
| 3  | ·1022                               | ·3416   | ·1675   | ·0447                             | ·0003 —                              | ·0001 —                     |
| 4  | ·1026                               | ·3105   | ·351  | ·0450                             | ·0001 —                              | ·0000                       |
| 5  | ·2032                               | ·6181   | ·2692   | ·0896                             | ·0002 +                              | ·0004 +                     |
| 6  | ·2049                               | ·5761   | ·2223   | ·0908                             | ·0006 +                              | ·0008 +                     |
| 7  | ·5088                               | 1·1301  | ·2606   | ·2232                             | ·0007 —                              | ·0000                       |
| 8  | ·5015                               | 1·0804  | ·2245   | ·2197                             | ·0010 —                              | ·0003 —                     |
| 9  | 1·0032                              | 2·0125  | ·3004   | ·4394                             | ·0020 —                              | ·0006 —                     |
| 10 | 1·0064                              | 2·0702  | ·3538   | ·4405                             | ·0023 —                              | ·0009 —                     |

In experiments 7, 8 and 9, the barium hydroxide solution was estimated by weight—in the others by volume. The calcium carbonate used was Iceland spar in the form of chips, but, though it was the best material available and considerably better than the best commercial calcium carbonate at hand, the test of drying below red heat and the igniting to the condition of caustic lime with a blow-pipe, proved it to be slightly



deficient in carbon dioxide. The observed correction of .0014 grm. for each gram of the carbonate is applied in the last column of the table.

The low results of the larger amounts of carbon dioxide, in contrast to the higher results of the smaller amounts, point to some action of the iodine upon the precipitated carbonate. It would be natural to suppose that such action would be greater upon the carbonate precipitated from a cold solution, and this proved to be the case. For when barium carbonate, precipitated under the conditions of the analysis described, was treated with 10 cm.<sup>3</sup> of iodine and boiled again, a loss of .0044 grm. of iodine (corresponding to .0008 grm. of dioxide) was found; but when barium carbonate was prepared by passing carbon dioxide through a cold solution of barium hydroxide until the presence of the acid carbonate was proved in solution by filtering a portion and boiling—thus insuring the complete destruction of the hydroxide—the precipitated carbonate, after filtering and washing, was acted upon by 10 cm.<sup>3</sup> of iodine solution to such an extent that .0253 grm. of iodine (corresponding to .0044 grm. of carbon dioxide) disappeared. The obvious inference is, therefore, that the carbonate should be boiled before the addition of iodine in the process.

The experiments of Table II were made like those of Table I, excepting in the following points: first, an ordinary flask of about 300 cm.<sup>3</sup> capacity, which fitted with a rubber stopper, was substituted for the more expensive ground stoppered absorption flask; secondly, the precipitated carbonate was boiled before adding any iodine; and thirdly, after iodine was added to a yellow color and boiled, a second amount of iodine was run in to a red color, but the mixture was not boiled again. By this treatment the iodine is kept from acting on the precipitated carbonate, at least to such an extent that the action is not appreciable, and from attacking the rubber stopper used; incidentally, it is kept from entering the trap, but one is used, nevertheless, to prevent contamination from the outside air. A separating funnel, reaching below the surface of the liquid, was found a convenient means of introducing the iodine without loss into the hot solution. A higher vacuum is required when the smaller flask is used, especially when large amounts of carbon dioxide are to be determined. A pressure of 200 mm. of mercury was found to be sufficiently low, and in no case did a flask of ordinary thickness and of 300 cm.<sup>3</sup> capacity collapse at that degree of exhaustion.

TABLE II.

|    | CaCO <sub>3</sub><br>taken<br>gram. | BaO <sub>2</sub> H <sub>2</sub><br>taken<br>gram. | BaO <sub>2</sub> H <sub>2</sub><br>found<br>gram. | CO <sub>2</sub><br>found<br>gram. | Error<br>on CO <sub>2</sub><br>grms. | Corrected<br>Error<br>gram. |
|----|-------------------------------------|---|---|-----------------------------------|--------------------------------------|-----------------------------|
| 1. | ·5023                               | 1·1385  | ·2851   | ·2190                             | ·0020—                               | ·0000                       |
| 2. | ·5056                               | 1·1414  | ·2801   | ·2211                             | ·0014—                               | ·0006 +                     |
| 3. | 1·0011                              | 2·0712  | ·3704   | ·4367                             | ·0038—                               | ·0002 +                     |
| 4. | 1·0030                              | 1·8788  | ·1736   | ·4376                             | ·0037—                               | ·0003 +                     |

The calcium carbonate used in this test of the smaller apparatus was the purest commercial article available; the error applied as a correction in the last column (·0040 gram. on carbon dioxide for a gram of carbonate) was determined by five closely agreeing analyses of various amounts in the larger apparatus.

The process, beside being delicate, is fairly rapid—the average time for a determination being about three-quarters of an hour.

It only remains to thank Prof. F. A. Gooch for many helpful suggestions and kindly advice in this investigation.

ART. XI.—*The Opisthoteuthidæ. A Remarkable New Family of Deep Sea Cephalopoda, with remarks on some points in Molluscan Morphology* ;\* by A. E. VERRILL.

THE genus *Opisthoteuthis* was first described and illustrated by me from a species (*O. Agassizii*) dredged by Mr. A. Agassiz, on the "Blake Expedition" off Grenada, in 291 fathoms.†

A second, but more imperfect, specimen was dredged by the Albatross, in 1884, off New Jersey, in 1058 fathoms.‡

The most remarkable external features of the genus are the posterior position of the siphon, which is also directed backward, and the close union of the pedal web with the entire under surface of the body. Thus the eight arms together with the broad web, which extends nearly to their tips, form an extensive disk-like ventral foot, adnate to the inferior or ventral surface of the body and extending beyond it on all sides. (Figures 1, 2, 3.) This arrangement is analogous to the position of the foot in the limpets and chitons among Gastropoda. Like those forms, *Opisthoteuthis* must be essentially a creeping and clinging mollusk, though not exclusively so, for the presence of small lateral fins indicates that it can swim, more or less. The siphon appears to be too small to be used for efficient locomotion.

The adhesion of the arms and web to the body must prevent

\* Abstract of a paper read before the National Academy of Science at Washington, D. C., April, 1896.

† Bulletin Mus. Comp. Zoology, vol. xi, p. 113, plates I and II, 1883.

‡ Trans. Conn. Acad. Sci., vol. vi, p. 408.

the free use of those parts as an umbrella-like swimming disk, as they are supposed to be used in *Cirroteruthis*, the nearest allied genus. It seems probable, however, that the creature could swim by means of an undulatory motion of the lateral borders of the pedal disk, as is done by certain planarians and by many tectibranch mollusks. The posterior position of the siphon naturally shows that the genital duct and intestine must terminate posteriorly, at its base, for in all other Cephalopoda these organs terminate at the base of the anteriorly situated siphon, where the outflow of water from the gill-cavity takes place. In the specimens described by me the viscera were too much decayed to be accurately described or figured.\*

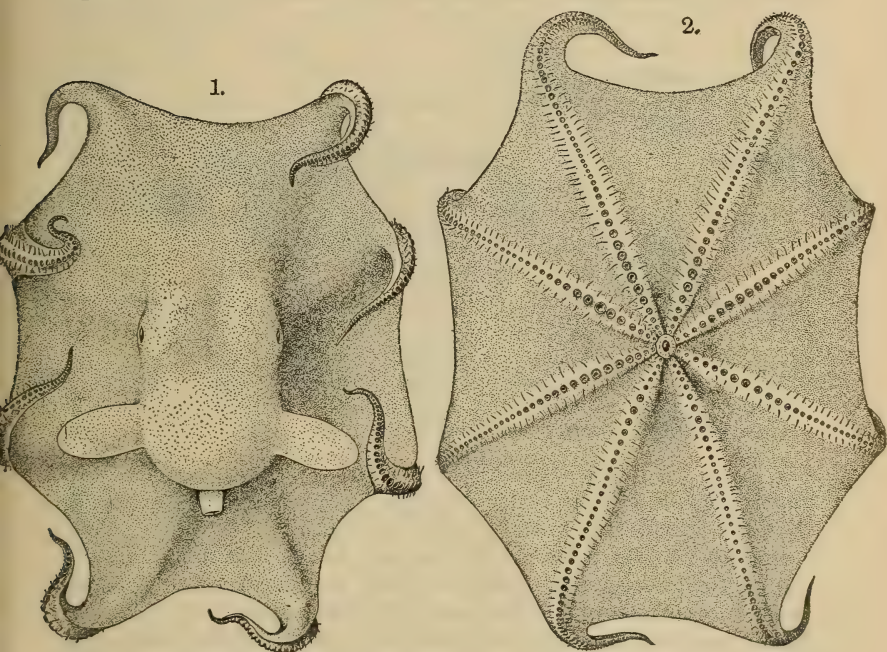


FIGURE 1.—*Opisthoteuthis Agassizii*, dorsal view. One-half natural size.  
FIGURE 2.—The same, ventral view.

This deficiency has been supplied recently by a closely related Japanese species (*O. depressa*) described by Messrs. I. Ijima and S. Ikeda.†

This species was taken in 250 fathoms and was examined while quite recent. It adds another to the numerous instances

\* This genus, like many other deep-sea cephalopods, etc., has a very soft gelatinous consistency and is difficult to preserve in alcohol unless the latter is kept ice-cold in an ice chest—a method not used at the time of these captures.

† Journal College Science, Imp. Univ., Tokio, vol. viii, pt. ii, 1895.



of closely allied deep water species occurring in Japanese and American waters. Their specimen was smaller than our own and the species differs in having smaller fins, a more depressed body, less prominent siphon, and some other characters, of no great importance.

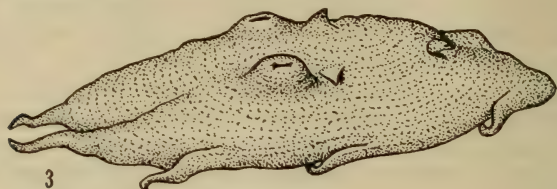


FIGURE 3.—*Opisthoteuthis depressa*, male, side view, natural size.

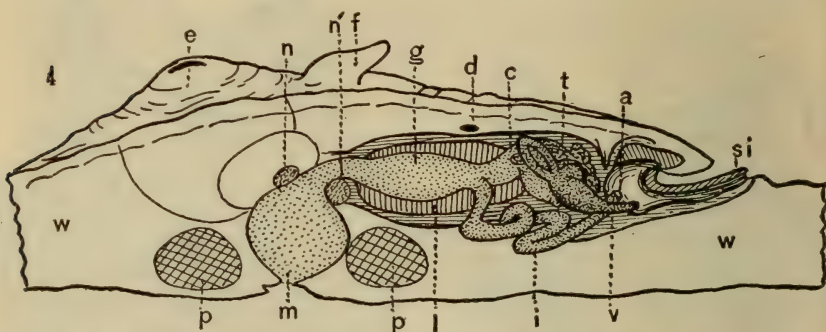


FIGURE 4.—*Opisthoteuthis depressa*, longitudinal section, enlarged. *e*, eye; *f*, fin; *p*, *p*, sections of arms; *w*, web; *si*, siphon; *d*, dorsal cartilage; *m*, mouth; *g*, stomach; *c*, coecum; *i*, intestine; *a*, anus; *l*, liver; *t*, spermary; *v*, sperm duct; *n*, *n'*, cerebral and suboesophageal ganglia.

I have here reproduced some of their figures of the Japanese species. It will be seen by the sectional view (fig. 4) that the intestine passes directly backward, with only slight convolutions and without any forward bend, to the anal opening at the base of the siphon. There is a small coecal appendage to the stomach. The pharynx has apparently no odontophore, which is also the case in Cirroteuthidæ, so far as examined. The jaws are after the usual cephalopod type. The reproductive organs (male) are posteriorly placed and the male duct (*v*) turns backward and opens at the base of the siphon. The gills (*b*, *b*, fig. 5) are short and have their apices turned backward. The gill cavity is partially divided by a median septum (*s*). The siphon is small and only slightly free from the pedal web at the tip. The gill opening is small and above the base of the siphon.

In the original description of this Japanese species the authors have made rather remarkable efforts, to reconcile the positions and relations of the parts with the theoretical,

strained, and as I believe, erroneous views of the orientation and homologies of the parts of cephalopods advanced by Huxley and still held by many other authors.

Thus they say that "the arched superior or posterior surface includes not only the posterior aspect of an ordinary cephalopod body but also the dorsal and ventral surfaces, as well as the outer surface of the umbrella. The head and body are thus flattened antero-posteriorly." According to their view, the siphon is "directed in the ventral, not in anterior direction, as is usually the case." They consider that "the ventral portion of the body is nowhere to be considered as concealed, except perhaps the mantle-rim, which is reflected inward at the branchial aperture. On the contrary, it stands, at least for the greater part, exposed more than ever, only with this peculiarity, that it forms a part of the general superior surface, thereby losing all definable boundaries from the real dorsal region or from the outer surface of the umbrella. Also that the original posterior end "is to be sought somewhere near the middle of the upper surface of the flattened body, behind the dorsal cartilage."

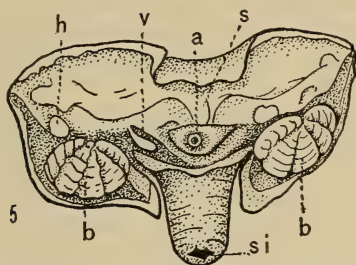


FIGURE 5.—The same as Fig. 3. Posterior view of gill cavity; *b, b*, gills; *h*, branchial heart; *s*, septum of gill cavity; *si*, siphon; *a*, anus; *v*, sperm duct.

The fact that such very unnatural and strained interpretations of the relations of parts have become necessary, ought to be sufficient to show that the theories on which they are based are erroneous. In fact, much of the interest connected with these forms consists in the fact that they throw much light on this very question of the relation of parts in the cephalopod body.

My own view of molluscan polarity is that the rudimentary cephalic ganglion which appears in the middle of the apical plate of the gastropod or bivalve larvæ, indicates the true anterior pole, while the mouth is behind the ventral edge of the apical plate, as in annelid larvæ. Later, by the progress of growth, the apical plate is reduced in size and the cephalic ganglions become more closely approximated to the mouth and œsophagus, so that the mouth may be considered as practically close to the anterior pole. The shell-gland, I think, may be taken to

indicate the position of the posterior pole, though many writers consider it as dorsal, being influenced by the position of the anus. The latter is formed later than the mouth and shell-gland and is too variable in position and mode of origin to be of much significance in this connection. Its normal and usual position in the larvæ is ventral, posterior to the mouth.

The theory adopted by Huxley, Lancaster, and many others,\* that the actual *dorsal* surface of a cephalopod is the anterior region; that the actual *posterior* end of the body is the dorsal side; and that the actual *ventral* side is the posterior surface, I consider as entirely erroneous and without any real foundation. One of the fundamental errors that has led to this theory is the wrong interpretation of the gastropod body. Thus Lancaster took the specialized flattened form, seen in limpets and chitons, as the normal or primitive form, and therefore made the long axis of the foot the antero-posterior axis of the body. When discussing the more common and more normal forms, with a body prominent above the foot, whether spiral or not, he called the actual body the "visceral hump" and treats it as a sort of hump, or dorsal appendage of the body. Hence, should it stand nearly at right angles to the foot, its front surface would become anterior and its back or ventral surface would become posterior. The same erroneous reasoning would naturally compel the ordinary cephalopod (fig. 6) to stand on its head (the arms or pedal organs being placed around the mouth), and in that position the body would correspond to the "visceral hump or dome" of the gastropods. In view of all that is now known of the embryology, anatomy, and homologies of the mollusca, such theories seem to me quite untenable. To me the more natural and correct view appears to be to consider the *foot* as a ventral appendage, and the "visceral dome" of a gastropod as the true *body*, whether it be high or low, flat or round, straight or twisted, and regardless of the position of the anal pore.†

That this is the true view can be easily shown by the study of the development of the larva in the proveliger‡ and veliger stages, for the larva early acquires definite anterior and posterior ends, and dorsal and ventral surfaces are differentiated

\* This view is adopted and discussed at some length in the recent *Text-Book of Comparative Anatomy*, by Dr. Arnold Lang, 1896.

† The anus is variously situated in gastropods that have the shell small or abortive, though the normal position is at one side of the neck-region in the gill-cavity, when a spiral shell is present, because the gill-cavity must necessarily be anterior in such cases. Huxley regarded the mouth and anus as representing respectively the "true morphological" anterior and posterior poles of the body. This view when applied to the various positions of the anus in Opisthobranchs, leads to very strange results.

‡ The stage that I call *proveliger* is that which precedes the formation of the functional anal pore and complete intestine, but in which the shell-gland is present. The subveliger is the next stage; in this the true shell begins but the intestine is still incomplete.



before the foot appears. The latter first arises as a small *ventral* protrusion, between the mouth and anus, which are very near together, in the subveliger stage of nearly all gastropods and bivalves.

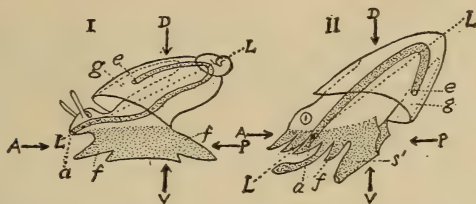


FIGURE 6.—Diagrammatic figures, to show axes. I, gastropod; II, cephalopod; A, P, longitudinal or antero-posterior axis, D, V, dorso-ventral axis, according to Lancaster; L, L', longitudinal axis as understood by the writer; a, mouth; e, anus; g, gill cavity; f, foot; s', siphon. (Copied from Lancaster with addition of lines L, L'.)

Taking this as a true exposition of the relation of parts in a gastropod, it is easy to prove that the body of a cephalopod corresponds to that of a gastropod, and that the actual dorsal is the true dorsal side; that the pedal organs (arms, web, siphon) are anterior and antero-ventral in all ordinary adult forms;\* and that the intestine makes a sharp turn and terminates in the median line, below the neck, at the base of the siphon,† and, therefore, behind the antero-ventral foot, which, indeed, is the primitive position in the larval state of most mollusca, and may, therefore, be called the *normal* position.

In *Opisthoteuthidæ*, on the contrary, the siphon and branchial cavity have been pushed backward to the posterior end of the body, far away from the mouth, owing to the peculiar development of the arms and web and their extensive union with the ventral surface of the body. The intestine has, therefore, lost its usual forward bend. Thus the family, in these respects, stands in about the same relation to other cephalopods that chitons do to ordinary gastropods.

These peculiarities seem quite sufficient to warrant the forming of a new family group. The *Opisthoteuthidæ* agree with the *Cirroteuthidæ* in having a single row of suckers on each arm, with two lateral rows of slender cirri; in having a broad web; in the presence of lateral fins; and, apparently, in lacking an odontophore.

The exceptional positions of the anus, siphon, gills, sexual and renal organs, in this family, make it agree, in these respect, with Lancaster's hypothetical "arche-mollusc."‡ However, in

\* In the embryo (squids, etc.) the arms arise below and behind the mouth and only surround the oral disk at a later period.

† The two folds that arise on each side of the embryo and finally unite to form the siphon are regarded as lateral parts of the foot.

‡ Encyclop. Brit. vol. xvi, p. 615. It should be stated that Lancaster, himself, does not claim that his "schematic mollusc" or "archetype" is such in the sense of a real primordial ancestral mollusk.

this group, this can only be regarded as an extreme secondary modification, due to a high degree of specialization connected with the adoption of a creeping and clinging mode of life, analogous to that of the chitons and limpets. It certainly cannot be regarded as a survival of a primitive arche-molluscan condition. It is not probable that the analogous positions of the organs in the chitons should be considered as arche-molluscan, or as proving that such were the original positions of parts in the ancestral forms of all mollusca. The chitons themselves are peculiarly specialized forms of gastropods, adapted to a special mode of life, and therefore cannot be considered as very primitive. Moreover, normal gastropods, so far as known, appeared earlier than chitons in geological time. Chitons are sparingly represented in the Lower Silurian, but normal gastropods are common in the Lower Cambrian, associated with the earliest forms of life yet known.



FIGURE 7.—*Loligo Pealei* in its natural position, at rest, from life. One-sixth natural size.

FIGURE 8.—*Octopus Bairdii*, young male, at rest, from life; b, hectocotyized arm.

The real arche-mollusca were far more probably similar to the simpler forms of gastropod and pteropod proveligers and veligers and, like these, free-swimming forms.

It is probable that many of the early cephalopods, such as *Orthoceras* and allies, having a long and very unwieldy shell, with a comparatively small last chamber, were not capable of swimming, but were either nearly sessile, and lived with the shell more or less buried in the mud, or else dragged the shell slowly over the bottom. The same was probably true of the irregularly curved forms, both of the Nautilacea and Ammonacea. Such forms would, however, have had active swimming young, perhaps of the veliger type, as a necessity for their wide dispersion.

The recent discovery\* that *Conularia* was sessile and attached at the apex, renders it probable that the genus belongs to the Cephalopoda, when its other characters are also considered. It is probable, in that case, that it represents a very primitive group, in which the initial secretion of the shell-gland of the veliger-like young served for attachment. As the group cannot be referred to any recognized order or sub-order, it may be designated as *Conulariacea*. It may, very likely, have been an ancestral form of Dibranchiata.

\* R. Ruedemann, Amer. Geologist, vol. xvii, p. 158, March, 1896.

## SCIENTIFIC INTELLIGENCE.

## I. CHEMISTRY AND PHYSICS.

1. *The fusibility of platinum in a blast-furnace fed by carbon.*—The oft-repeated assertion that platinum can be fused in a furnace fed with carbon and air has been subject to some doubt on account of the possibility of the contamination of the metal by carbon or other substances in the furnace. VICTOR MEYER has now succeeded in melting the metal when enclosed in a thick block of refractory earth in such a manner that no impurities were taken up. The fuel used was retort carbon broken up in pieces of the size of a hazel-nut, and the air was supplied by a powerful blast. An alloy of 75 parts of platinum and 25 parts of iridium, exposed to the same temperature in another cavity of the same block of refractory material, remained entirely unaffected.—*Chem. News*, lxxiii, 235.

H. L. W.

2. *The condition of the water in analcite.*—In making an analysis of analcite of peculiar form and optical properties CHARLES LEPIERRE has taken occasion to determine the temperatures at which the water is given off. He found that it lost almost exactly half its water upon long heating to constant weight at 200°, and that this loss was not increased at 300°. At 440°, however, all of the remaining water was disengaged. The higher temperatures, 300° and 440°, were obtained by the use of the vapors of a high-boiling petroleum-product and of sulphur respectively, so that these temperatures may be regarded as reliable. The author believes that his results indicate that the formula representing the composition of the mineral is much simpler than that proposed by F. W. Clarke, since according to the latter formula the water would not be expected to be given off in two equal parts. He proposes the formula  $H_4Na_2Al_2Si_4O_{14}$ , and develops it in such a manner that four hydroxyl groups are attached to the silicon atoms.—*Bull. Soc. Chim.*, III, xv, 561.

H. L. W.

3. *Quantitative separations by means of hydrogen peroxide.*—During the past five years JANNASCH and his pupils have studied a number of separations based upon the oxidizing action of hydrogen peroxide, usually in alkaline solution. The reactions utilized are chiefly the precipitation of manganese, lead and bismuth as peroxides, and the oxidation of chromium compounds to chromates. The peroxides are precipitated in most cases by pouring the moderately acid solution of the salts to be operated upon into a mixture of an excess of ammonia and hydrogen peroxide with continual stirring. In the case of lead and bismuth the operation is performed in the cold, while with manganese the whole is warmed for a short time to cause the precipitate to settle. Separations are thus made from zinc, nickel, cadmium, mercury, silver and copper. In the separations from arsenic sodium hydroxide is used in place of ammonia, and in some instances the separation is



made in the presence of potassium cyanide. Many of the separations must be repeated in order to attain completeness. The peroxides dissolve with great readiness in a mixture of nitric or hydrochloric acid and hydrogen peroxide, the latter reagent acting in this case as a powerful reducing agent. A serious difficulty with this method arises from the presence of impurities, especially silicic acid, in commercial hydrogen peroxide. The reagent can, however, be obtained in a pure condition by distillation, according to Wollenstein's method, under diminished pressure.—*Zeitschr. anorg. Chem.*, xii, 134, etc. H. L. W.

4. *The use of "heavy solutions" in the examination of commercial fertilizers.*—Thoulet's solution, which has been so extensively used by mineralogists, has been applied by A. P. BRYANT to the separation of mineral phosphates from phosphates existing in the form of bone, tankage, etc. Heretofore there has been no means of distinguishing the cheaper "rock phosphates" from the "organic phosphates," which are undoubtedly more readily available as food for plants, as they occur in prepared fertilizers as sources of "insoluble" phosphoric acid. The author uses a solution of specific gravity 2.26, and gives the following table of the specific gravities of substances commonly occurring in the materials under consideration :

|  |             |
|--|-------------|
| Bone and other organic matter, less than | 2.0         |
| Gypsum                                   | 2.3         |
| Aluminium phosphates                     | above 2.3   |
| Iron phosphates                          | about 2.6   |
| Silica                                   | 2.65        |
| Calcium phosphates                       | 2.9 to 3.55 |
| Fluorite                                 | 3.2         |

The separation is applied after treatment with water and drying, but before extraction with ammonium citrate. The simple apparatus recommended by the author consists of a plain glass tube about 1.3<sup>cm</sup> in diameter and 20<sup>cm</sup> long, which is attached by means of a short piece of rubber tubing to a tube of the same diameter about 7<sup>cm</sup> in length and closed at the end. The material is placed in this apparatus with the heavy solution, and, after corking, is thoroughly agitated. After the liquid has become perfectly clear the rubber tube is closed with a pinch-cock and the two portions are washed and submitted to analysis. A number of test-experiments, made with mixtures of known origin, gave extremely satisfactory results.—*Jour. Am. Chem. Soc.*, xviii, 491. H. L. W.

5. *The action of nitric acid upon potassium cobalti-cyanide.*—In attempting to produce compounds analogous to the nitroprussides by the action under consideration, JACKSON and COMEY, while failing in this attempt, have obtained an interesting, new class of salts. By long-continued boiling of potassium cobalti-cyanide with strong nitric acid, the liquid gradually became dark red and finally suddenly changed to a semi-solid gelatinous mass.

After drying in a vacuum the substance showed the composition corresponding to the formula,  $\text{KH}_2\text{Co}_3(\text{CN})_{11} \cdot \text{H}_2\text{O}$ . The substance, after drying, slowly dissolves in water at  $60^\circ$ , but leaves only a varnish upon slow evaporation. The solution gives precipitates with the salts of most of the metals. The silver and barium salts, thus produced, gave results upon analysis corresponding to the formula  $\text{Ag}_3\text{Co}_3(\text{CN})_{11} \cdot \text{H}_2\text{O}$  and  $\text{BaHCo}_3(\text{CN})_{11} \cdot 1\frac{1}{2}\text{H}_2\text{O}$ .—*Berichte*, xxix, 1020.

H. L. W.

6. *The substitution of various substances in the place of the water of zeolites*.—GEORGES FRIEDEL has shown that the water of certain zeolites can be replaced by ammonia. He found also that hydrogen sulphide is absorbed with great energy by dehydrated chabazite and harmotome, giving, after long exposure to the gas, an increase in weight greater than that of the water lost. The product lost hydrogen sulphide when exposed to the free air, taking up water and returning to its original condition. Carbonic acid acted with the same species in the same way. Ethyl alcohol was absorbed slowly but abundantly. Hydrogen was condensed by them very rapidly, but its loss was so rapid that no accurate weights could be made. Finally the author has made an observation which is of great importance to the analytical chemist, viz: that atmospheric air is absorbed so abundantly as to render inexact the determination of water by simple loss by ignition, at least unless fusion takes place. Chabazite absorbed in a desiccator in a few minutes a quantity of air amounting to 1.77 per cent of its weight. The presence of this air was easily shown by putting the dehydrated material in a tube filled with mercury, then adding a few drops of water, when the crystals fell to powder and discharged a large volume of gas. This air when analyzed showed the existence of only about 8 per cent of oxygen, and it was, therefore, very different in composition from ordinary air.—*Compt. Rend.*, cxii, 1006.

H. L. W.

7. *Elementary Treatise in Electricity and Magnetism*, founded on Joubert's "*Traité Élémentaire d'Électricité*," by G. C. FOSTER and E. ATKINSON, 552 pp., London, New York and Bombay, 1896 (Longmans, Green & Co.).—The *Elementary Treatise* of Joubert is well known for its highly clear and systematic presentation of the fundamental principles of electricity and magnetism. This excellent work is now made available for the use of the English-speaking public in general, and in accomplishing this the editors have performed an important service to English and American students. The present work is, however, more than a translation, for the English editors have to some extent modified the method of presentation, in particular as regards the introduction of the method of viewing electrical phenomena originated by Faraday and developed by Maxwell. They have thus throughout made use of the conception of lines and tubes of force, also of the charge of an electric field as a whole rather than that of the conductors on whose surface the charge appears. They have also simplified the work for the

elementary student by giving in certain cases the successive steps of the mathematical discussions in greater detail, so that the whole reasoning can be more easily followed.

## II. GEOLOGY AND NATURAL HISTORY.

1. *United States Geological Survey*.—The following portions of the 16th annual report, 1894-95, have appeared\*:

Public Lands and Their Water Supply, by F. H. Newell, Part II, pp. 459-533, pls. 5. Now that the humid public lands have been disposed of, and practically one-third of the total extent of the United States (not including Alaska) semi-humid and arid, is still vacant, it becomes necessary to know its water supply in order to determine the conditions of prosperous development. The report contains a map showing the relative location of forests, woodlands and irrigated areas, and it is gratifying to know that the appropriations for this work, which must furnish the information for the intelligent administration of public lands, is increasing.

The other papers of Part II of the 16th annual, lately issued and completing Part II, are:—

Geology of the Cripple Creek Mining District, Colorado, by Whitman Cross and R. A. F. Penrose, pp. 1-209.

Geology of Road Building Stones of Massachusetts, by N. S. Shaler, pp. 283-328.

Geology of the Mercur Mining District, Utah, by J. E. Spurr, pp. 344-454 (abstract this Journal, IV, vol. i, p. 395).

Water Resources of a Portion of the Great Plains, by Robert Hay, pp. 535-588.

The following BULLETINS have appeared recently:

The Disseminated Lead Ores of Southeastern Missouri, by Arthur Winslow, Bull. 132, pp. 31, pls. 6, 3 colored maps and sections. This report is an explanation of the work published in vols. vi and vii of the present State Geological Survey of Missouri.

Contributions to the Cretaceous Paleontology of the Pacific Coast: The Fauna of the Knoxville Beds, by T. W. Stanton, Bull. 133, p. 132, 20 pls. (abstract this Journal, IV, vol. i, p. 320).

The Cambrian Rocks of Pennsylvania, by C. D. Walcott, Bull. 134, p. 43, pls. 15. This paper records observations made during the summer of 1892 and 1893 upon the belt of Lower Paleozoic rocks and contains a map showing the distribution of the Cambrian, Silurian and Mesozoic strata in the southeastern portion of Pennsylvania. On page 33 Mr. Walcott says that "The discovery of the *Olenellus* or Lower Cambrian fauna in the Reading sandstone practically completes the correlation of the South Mountain, Chickies, and Reading quartzites, and establishes the correctness of the early correlations of McClure, Eaton, Emmons, and Rogers. They all considered the basal quartzite as the same

\* Six papers in pt. I of the 16th annual are yet to appear.



formation from Vermont to Tennessee." "The superjacent limestones carry the *Olenellus* fauna in their lower portions in northern and southern Vermont, eastern New York, New Jersey and Pennsylvania. To the south of Pennsylvania the lower portions of the limestones appear to be represented by shales, and the Upper and Middle Cambrian faunas are found in the lower half of the Knox dolomite series of Tennessee, and they will probably be discovered in the same series in Virginia and Maryland when a thorough search is made for them. The same may be predicted, but with less assurance, for the northern belt of limestone crossing Pennsylvania into New Jersey, as the limestones between the *Olenellus* zone and the Trenton zone represent the intervals of the Middle and Upper Cambrian and the lower Ordovician, or the Calcareous and Chazy zones of the New York section. The working out of the details of this section in southeastern Pennsylvania is an interesting problem left for solution to some geologist who has the necessary paleontologic training, and who will not be discouraged by the prospect of a good deal of hard work before the desired result can be obtained."

"The problem of where to draw the line in this series of limestones, on a geologic map, between the Cambrian and Ordovician, is one that will seriously embarrass the geologist, but I anticipate that either lithologic or paleontologic characters will be discovered by which the two groups can be differentiated."

The final seven pages and six plates are devoted to the consideration of intraterritorial conglomerates,—that is, of conglomerates "formed within a geologic formation of material derived from and deposited within that formation." In explaining their origin, Mr. Walcott believes that the sea bed was raised in ridges or domes above sea level, and thus subjected to the action of shore ice, if present, and the ærial agents of erosion.

The following are the FOLIOS which have been recently issued:

- No. 21. Pikesville, Tenn., lat.  $85^{\circ}-85^{\circ} 30'$ , long.  $35^{\circ} 30'-36^{\circ}$ , by W. C. Hayes.
- No. 22. McMinnville, Tenn., lat.  $85^{\circ} 30'-86^{\circ}$ , long.  $35^{\circ} 30'-36^{\circ}$ , by W. C. Hayes.
- No. 23. Nomini, Md. & Va., lat.  $76^{\circ} 30'-77^{\circ}$ , long.  $38^{\circ}-38^{\circ} 30'$ , by N. H. Darton.
- No. 24. Three Forks, Mont., lat.  $111^{\circ}-112^{\circ}$ , long.  $45^{\circ}-46^{\circ}$ , by A. C. Peale.
- No. 25. Loudon, Tenn., lat.  $84^{\circ}-84^{\circ} 30'$ , long.  $35^{\circ} 30'-36^{\circ}$ , by Arthur Keith.

Crater Lake, (Oreg.), Special Topographic Sheet with illustrations and geologic text on back, by J. S. Diller.

2. *American Paleontology Prize*.—A prize of fifty dollars is offered by Prof. G. D. HARRIS, editor of the *Bulletins of American Paleontology*, for "the best American (North, Central or South) paleontological article presented for publication, as a separate bulletin, before May 1, 1897. The article must be a well

written original monograph or report upon some special problem studied in the field or laboratory or both, i. e., not a mere compilation from books. This report may contain from 50 to 200 pages and from 5 to 10 full page plates of the size of the bulletins. It may be written in any language using Roman characters. The judges in awarding the prize shall have the power to divide the prize in two equal parts in case of doubt between the merits of two excellent articles, or to withhold the prize in case no suitable article appears. All communications regarding the matter should be addressed to Prof. G. D. Harris, Department of Paleontology, Cornell University, Ithaca, N. Y. H. S. W.

3. *The Midway Stage*, by G. D. HARRIS (Bull. Am. Pal., No. 4, Ithaca, N. Y., June 11, 1896, pp. 1-156, plates 1-15).—This fourth number of Professor Harris' Bulletins discusses, in the author's thorough way, the formations and fossils of the lowest midway stage of the Eocene in the Southern states.

In the course of the paper the author has shown that there is unconformity between the Cretaceous and overlying Eocene east of the Mississippi, and a contact between the two is photographed in Plate II.

The author's study of the species examined leads him to the following conclusions, as summarized in a communication received from him.

"All of Gabb & Safford's 'Ripley Cretaceous' fossils from Hardeman Co., Tenn., are Eocene.

"The uppermost 100 ft. of Smith & Johnson's 'Cretaceous' section at Prairie Bluff is Eocene, as proven by an abundant and typical Eocene fauna.

"The beds at and to the south of Palmer's mill, Wilcox Co., Ala., referred to the 'Cretaceous' by Smith & Johnson (Bull. 43, U. S. G. S.) are all Eocene. Here, as on the Alabama River, they have their contact line 100 or more feet too high.

"*Euclimatoceras ulrichi*, instead of being confined to one calcareous bed, a few feet in thickness, is now known to occur in every important bed of the Midway stage in western Alabama, from the contact (Cret.-Eoc.) below to and including the Matthews landing horizon.

"The Chattahoochee River Midway limestones are the representatives of the whole Midway stage to the west, and are not the outgrowth of an insignificant rock in western Alabama."

The paleontological part of the work gives the description, figures and synonymy of all the well authenticated species of the Midway stage and of forty-five new species and several varieties. The genera *Perna*, *Isocardia* and *Keilostoma* are reported for the first time from North American Eocene deposits. H. S. W.

4. *The Student's Lyell, a Manual of elementary Geology*, edited by JOHN W. JUDD, pp. 635, figs. 736. London, 1896. (John Murray).—This once standard student's manual of geology is presented with corrections and additions, the latter particularly in the way of illustrations of newly discovered fossils, but retaining the

chief characteristics of the author. The application of the term *Epigene* to include both aqueous and volcanic rocks, in contrast to the plutonic igneous rocks to which Lyell gave the name *Hypogene*, shows how modern science has already gone beyond the theories of the great master. We observe a few paragraphs in which the progress of science and even political classification in the United States are disregarded. Thus "Freshwater strata of western territories" and "greensands of New Jersey" give a very inadequate notion of the present knowledge of the "Cretaceous" in North America (p. 336). The same remark applies to "Limestones and shales of the Appalachians" as the only indication of the American representative of the lower Carboniferous (p. 395). We notice (p. 431) that the "Calceiferous sandstone" is made to be the equivalent of the upper division of the Cambrian; and the earliest trace of fishes is described as "(?) Ordovician, California," which probably refers to the Cañon City, Colorado, beds. Many valuable additions are made in the way of illustration to the 1871 edition of "The Student's Elements of Geology" which formed the basis of the present volume. H. S. W.

5. *Chloritoid from Michigan—a Correction*, by W. M. H. HOBBS. (Communicated.)—In a paper published in this Journal (vol. 1, p. 121, 1895, I mentioned the occurrence of a mineral in blocks on the south side of Michigamme Lake, Michigan, and gave sufficiently full chemical and optical data to determine it as chloritoid. Since the paper was published Dr. A. C. Lane has called my attention to the fact that the chloritoid of this locality is probably nearly or quite identical with that of the Champion Mine described by Kellar and Lane in this Journal (vol. xlii, p. 499). A more careful examination of the mineral shows that it is certainly triclinic as determined by Lane, the most important evidence of this being the fact that prismatic sections which exhibit the deep blue absorption of  $\delta$  have extinction angles with the base of  $20^\circ$  or more. Figure 6 of my paper, which is drawn to represent an approximately monoclinic mineral, is therefore incorrect as regards the crystallographic orientation. I should also add that on page 31 of the fifth volume of the Geological Survey of Michigan a reference is made by Rominger to the occurrence of chloritoid in loose blocks south of Michigamme village. This volume was issued shortly before my paper, but my efforts to secure a copy had been unsuccessful.

In a paper published as a bulletin of the University of Wisconsin (Science Series, vol. 1, No. 4, p. 140) in enumerating the several types of marcasite from the ore deposits of southern Wisconsin and northern Illinois, one type (type 2) was mentioned which was supposed, from the direction of apparent indistinct striations on the base, to represent a tabular type bounded on the long edge by the macropinacoid. The crystals were very imperfect and almost completely altered to limonite. Subsequent examination of similar but better specimens from the same locality reveals the fact that this type is produced by the distortion of twinned individuals, the face marked  $\alpha$  in the figure being not the macropinacoid but the prism.



6. *Report of the Section of Chemistry and Mineralogy*, by G. C. HOFFMANN. Part R, Ann. Rep. Geol. Surv., Canada, 1896.—This report, which is largely devoted to technical analyses and assays, the analyses being chiefly of a series of marls, contains, however, some notes of general interest on the occurrence of minerals in Canada. We note the following:

(1.) Celestite occurs in a vein two feet wide cutting limestone in the township of Lansdowne, Leeds Co., Ontario. Is at times quite pure, though often associated with calcite and galena. Colorless, sometimes pale bluish or reddish, semi-transparent: crystalline, though distinct crystals are not mentioned. An analysis by Mr. R. A. A. Johnston gave:

| SrO   | BaO | CaO  | SO <sub>3</sub> |
|-------|-----|------|-----------------|
| 56.31 | tr. | 0.11 | 43.51 = 99.93   |

(2.) Tetrahedrite containing lead, from the Antelope claim Kaslo Slocan camp, West Kootanie Dist., Brit. Col., occurs associated with galena, sphalerite, pyrite and quartz. Massive, iron-gray in color. Sp. gr. 5.08. Analysis by Mr. R. A. A. Johnston, after deducting quartz, gave

| Sb    | As  | Cu    | Ag    | Pb   | Zn   | Fe  | S              |
|-------|-----|-------|-------|------|------|-----|----------------|
| 28.22 | .23 | 22.14 | 11.20 | 9.38 | 6.22 | .93 | 21.68 = 100.00 |

(3.) Leucite occurs in smoke-gray, sub-translucent crystals up to 2.5<sup>cm</sup> in diameter, embedded in a dark gray rock which was found as boulders in the auriferous gravel of the Horsefly Mine on Horsefly River about seven miles above its entry into Quesnel Lake, Cariboo Dist., Brit. Col.

L. V. P.

7. *Les Mines d'Or du Transvaal*, par L. DE LAUNAY. 8°, 540 pp., 11 pl., 81 fig. Paris, 1896 (Baudry & Cie).—The great prominence that the gold mines of the Transvaal region have assumed in the past few years, due to their great extent and wonderful richness and to the political complications to which their wealth has led, renders the appearance of this work especially well-timed.

The first portion of the book is devoted to a general description of the country, the climate, productions, means of communication, a description of the chief towns, its history and a very full account is given of the organization of the mining industries from financial, legal and economic or industrial standpoints. The second part comprises a geological account of the ore deposits, their origin and method of occurrence, while a third portion describes the methods of mining, the treatment of the ores and the various metallurgical processes employed. In conclusion the author gives in a general résumé the present state of the mining industry and its probable future.

As the work is well illustrated and written in a style that is neither too technical nor judicially severe, it will prove of value not only to the scientific expert and mining engineer, but to that portion of the general public as well who are interested in the region.

L. V. P.

8. *Lehrbuch der Ökologischen Pflanzen-geographie*, von Dr. EUGEN WARMING. Berlin, 1896, pp. 412.—Professor Warming, of Copenhagen, has presented in this interesting work some of the more important facts regarding the relations of plants to their surroundings. The adaptations of vegetation are classified in a simple manner which gives the impression of an exhaustive system. All the factors are considered in turn and the response of plants to all external influences is stated clearly. Mutual relations of plants and animals are taken up in a very attractive and thorough fashion, and without any attempt at exaggeration. The biological associates are properly grouped and described, and, lastly, the struggle between these groups is dealt with in a graphic style. This contribution to geographical botany merits an early and good translation into the English language.

G. L. G.

9. *Missouri Botanical Garden. Seventh Annual Report*. St. Louis, Mo., 1896, pp. 209.—Professor TRELEASE gives a valuable monograph on the Juglandaceæ of the United States in which he has tabulated characters presented by the fruit, twigs, bark, and buds. He states that, owing to the publication of the seventh volume of Professor Sargent's *Silva of North America*, he does not consider it desirable to publish the entire manuscript he had prepared. Even in its abbreviated form it is a very important addition to the literature of the subject. It is characterized throughout by the excellent qualities which mark all of Professor Trelease's work.

From Miss Mulford we have a careful study of the Agaves of the United States. The histological and economic aspects of these plants have received much attention from her, and are here clearly described.

Mr. C. H. Thompson treats of the ligulate Wolfias of the United States.

The Director presents an interesting account of the pre-Linnæan library presented to the Garden by Dr. E. Lewis Sturtevant of Massachusetts. This exceedingly valuable library will be of the greatest use in the researches in regard to cultivated plants which are prosecuted under Professor Trelease's direction.

G. L. G.

### III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The height of the luminous night-clouds*.—The Observatory at Berlin is about to publish the results of an elaborate investigation of the luminous night-clouds by Dr. Jesse. The author gives in the *Astronomische Nachrichten*, No. 3347, some of the principal results of his observations and discussion. They are based on photographs taken in the months of June and July in the years 1889-91 at Steglitz, Berlin, Nauen and Rathenau. A striking peculiarity of the results is the almost constant altitude of the clouds. Although the photographs were not strictly simultaneous, yet the computed heights of points in these clouds lie between 80.27 and 88.53 kilometers, the mean height of the series being 82.08.

2. *Publications of the Washburn Observatory of the University of Wisconsin*, vol. ix, pp. 258, 4to, Madison, 1896.—This volume contains, 1st, the results of an elaborate investigation of the aberration and atmospheric refraction by Prof. Comstock, and 2d, observations of the right ascension of certain stars made by Mr. Flint with a prism apparatus.

3. *Mathematical papers read at the International Mathematical Congress held in connection with the World's Columbian Exposition, Chicago, 1893*, 8°, pp. xvi, and 411. New York, 1896. (Macmillan & Co. for the American Mathematical Society: \$4.00).—This volume is vol. i of papers published by the Am. Math. Soc., the society having given \$600 towards its publication. It is edited by a committee of the congress of which Prof. E. H. Moore was chairman, and it contains forty-five papers furnished by American, German, Swiss, Austrian, French and Russian mathematicians. With such a wide circle of contributors the volume naturally covers subjects of widely varied character. It is, of course, a volume that must find place in every university library.

4. *American Association for the Advancement of Science*.—The forty-fifth meeting of the American Association is to be held in Buffalo, N. Y., from August 22d to 29th. The preliminary program, recently issued by the permanent secretary, F. W. Putnam, gives the places and times of meeting, statements as to excursions and so on. Mr. Putnam's address is Salem, Mass., until August 17th, after that, A. A. A. S., Buffalo; the address of the local secretary is Mr. Eben P. Dorr, A. A. A. S., Buffalo.

5. *The British Association for the Advancement of Science*.—The sixty-sixth meeting of the British Association is to be held at Liverpool, from September 16th to 23d.

6. *Journal of Physical Chemistry*.—The attention of the readers of this Journal is called to the prospectus inserted in the present number of the new *Journal of Physical Chemistry*, the publication of which is to be commenced at Ithaca, N. Y., under the editorship of Professors Wilder D. Bancroft and Joseph E. Trevor. It merits the cordial support of all interested in this department of science.

#### OBITUARY.

JOSEPH PRESTWICH, the distinguished English geologist, died in June at the age of eighty-four years.

M. DAUBRÉE, the eminent French geologist, died at Paris on May 29, at the age of eighty-two years. His long life bore abundant fruit and gave him a foremost place among the workers in science, not only in his own country, but in the world at large. His researches were numerous, and of the highest value; they covered a wide field, embracing particularly experimental geology, the artificial production of minerals and the characters of meteorites. Those who had the privilege of his personal acquaintance will never forget the peculiar charm of his courtly, genial manner, which expressed his high character and kind, generous heart.



# NEW WESTERN MINERALS.



Mr. English has been in the far West on an extended collecting trip for over a month past and has met with unparalleled success. His trip is designed to cover Lake Superior, Colorado, New Mexico, Arizona, California and Utah, and we are already able to offer our customers many extra choice specimens which have been sent on by express.

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*Obituary*—JOSEPH PRESTWICH: M. DAUBRÉE, 90.

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THE

# AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

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ART. XII.—*The Molluscan Archetype considered as a Veliger-like Form, with discussions of certain points in Molluscan Morphology* ;\* by A. E. VERRILL.

A NUMBER of years ago Professor R. Lancaster published diagrammatic figures and a description of what he called a "schematic mollusc" or an "archemollusc." He distinctly stated, however, that he did not claim that it was an archetype in the sense of having been the actual original form from which all later mollusks have been developed.† His archetype has, however, been assumed by many later writers to represent the actual primitive or ancestral mollusk, from which all modern forms may have been derived.

It is my present purpose to give some reasons for considering such an idea as unwarranted by our actual knowledge, and to explain what I believe to have been the actual archemollusks, or primitive forms of Mollusca.

Observation and experience in many other cases show that we cannot expect to find an archetypical or primitive form of a great and diversified group among the highly specialized adult forms now living. We should look for such primitive

\* Abstract of a paper read before the National Acad. of Science, Washington, D. C., April, 1896.

† Encyclop. Britannica, ed. ix, vol. xvi, p. 635, 1883. His statement is as follows: "Such a schematic mollusc is not to be regarded as an archetype, in the sense which has been attributed to that word, nor as an idea present to a creating mind, nor even as an epitome of developmental laws. Were knowledge sufficient, we should wish to make this schematic mollusc the representation of the actual molluscan ancestor from which the various living forms have sprung. To definitely claim for our schematic form any such significance in the present state of knowledge would be premature, but it may be taken as more or less coinciding with what we are justified, under present conditions, in picturing to ourselves as the original mollusc or arche-mollusc."

forms among the early larval stages of those groups that undergo a marked metamorphosis, and especially among those larval forms that reappear in groups differing so widely among themselves, when adult, that they must be considered as distinct classes and orders. In the case of the Mollusca, we have, in the form of larva known as the *veliger*, and in the slightly younger stages that I have called the *proveliger* and *subveliger*,\* organisms that swim free, and often seek their own food, and which, in all respects, seem to have claims to be considered as the nearest living representatives of the ancestral molluscan archetype, or archetypes, for it is quite probable that the different classes of Mollusca have descended from distinctly differentiated, veliger-like organisms. Which of these may have been the most primitive it may not be possible to determine.

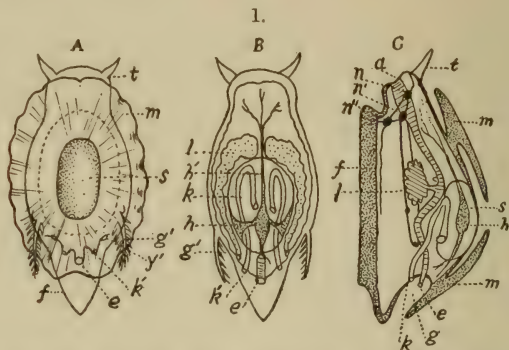


FIGURE 1.—Schematic mollusk, after Lancaster. A, dorsal; B, horizontal section; C, longitudinal section. *f*, foot; *m*, *m*, mantle; *s*, shell; *t*, tentacle; *g*, gill-cavity; *g'*, gill; *a*, mouth; *e*, anus; *h*, heart; *h'*, aorta; *k*, nephridium; *k'*, nephridial duct; *l*, liver; *i*, gonad; *y'*, genital pore; *n*, *n'*, *n'*, ganglions.

The archetype suggested by Lancaster was, to a very large extent, based on the actual structure of living chitons, which are peculiarly specialized creeping gastropod mollusks, in which the anus has secondarily acquired a posterior position, and in which the genital and renal organs are symmetrically placed on each side, posteriorly. These are conditions very unusual in adult mollusks generally,† and probably never to be found in the larval forms, unless in those of the chitons and allies (*Isopleura*).

In order that the real characters of Lancaster's "archemollusc" may be clearly understood, I have reproduced here three

\* This Journal, p. 78, July, 1896.

† Adult bivalves generally have the anus posterior and median, but the nephridial and sexual ducts are ventral and lateral. In the veliger stages the anus is ventral and near the mouth, as usual. It gradually shifts backward as the foot grows larger.



of his diagrammatic figures. (Fig. 1, A. B. C.) This hypothetical form has a convex or low dome-like body with a simple conical dorsal shell, partly enclosed in a dorsal mantle cavity, instead of the series of eight shelly dorsal plates found in chitons. (Fig. 2.) It has a well-developed, broad, ventral,

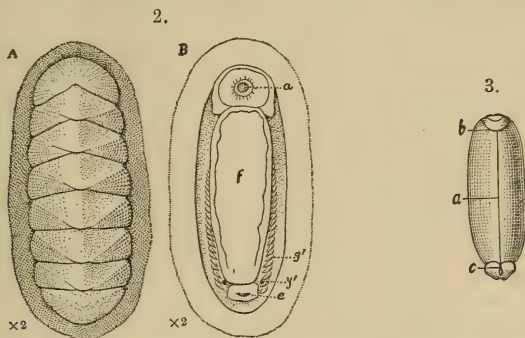


FIGURE 2.—One of the Chitonidæ (*Trachydermon exaratus*, from life). A, dorsal and B, ventral views; a, mouth; e, anus; f, foot; g', gills; y', genital pore. FIGURE 3.—*Neomenia carinata*. Ventral view. a, groove or rudimentary foot; b, mouth; c, anal area and rudimentary mantle.

creeping foot, like that of chitons and many other gastropods. It has a single posterior pair of pectinate gills (fig. 1, g'), instead of a row on each side, as in chitons. It has the head and tentacles (t) of a normal gastropod, instead of the degenerate or abortive condition of these organs found in the chitons. (Fig. 2, B.) Even should we admit that this may represent the primitive form of true gastropods, it would seem impossible to derive from it a cephalopod or a bivalve, for the parts are represented as so highly modified and specialized that it would require us to imagine a backward development in order to return to a specialized condition of head, foot, shell, gills, intestine, etc., in order to find a starting point from which the bivalves and cephalopods might have been derived.

But the chitons, themselves, undergo a marked metamorphosis and have a veliger stage somewhat different from that of ordinary marine gastropods. Therefore, if we are to consider this group as a primitive one, even among gastropods, it would be more natural to believe that the larvæ of chitons approach more nearly to real archetypical forms than the adults do. This is doubtless true, for the chiton larva is a peculiar and rather simple veliger, with a rudimentary velum and a simple band of cilia. It has, at first, only a simple shell-gland, like the veligers of other gastropods. Its ventral, or foot-region, early acquires a great longitudinal development, so that when the anus first appears it is situated farther back than usual.

This is, however, an exceptional condition in veligers, whether of gastropods, bivalves, or pteropods, and therefore cannot be rightly regarded as archetypal.

The allied and still more peculiar Aplacophora (fig. 3) must be regarded as degenerate mollusks that have taken on worm-like forms adapted to their worm-like mode of life, burrowing in the mud. In consequence of this, they have lost the cephalic sense organs, shell, etc., and the foot and odontophore have become nearly abortive. This group, though lowly organized, certainly cannot be regarded as a very primitive one, but it may have been derived from the primitive chitons (Placophora), by degeneration.

The latter, although not to be regarded as archetypal for mollusks in general, nor even for gastropods, as a whole, must be considered a very early offshoot from the gastropod stem, and as a group which has developed in a very divergent line.\* Fossil chitons occur as early as the Lower Silurian period, but normal gastropods of many kinds are abundant in much earlier periods. A considerable number occur even in the early Cambrian. Of these several are limpet-like forms, and therefore were even then much modified from the real primitive forms, for all limpet-like living forms are known to have been derived from spiral shells, and still have a more or less spiral shell in the veliger stage. (Fig. 8.)

Various well developed bivalves and cephalopods also occur in the Lower Cambrian rocks. Most of the classes and many of the orders and families had already been well differentiated before these earliest known fossiliferous rocks were deposited. Therefore we can hardly expect to ever find actual molluscan archetypes as fossils. Some of the very ancient fossil gastropods were, however, closely allied to certain living genera, such as *Pleurotomaria* and *Fissurella*. In these there are two anterior paired gills, two auricles, and several other very primitive characters. This group, in fact, must be regarded as more primitive even than the chitons, and therefore nearer to the true gastropod archetype. Unfortunately we do not know the larval stages of *Pleurotomaria*, but allied genera have veligers of the ordinary form.

But for archetypal forms resembling those from which the several classes of mollusks may have been developed in pre-Cambrian ages, we must, I think, look among the early larval stages of existing Mollusca, as already suggested. From the simpler forms of the veligers and subveligers of gastropods and pteropods we may derive our clearest ideas of the earliest forms of primitive molluscan life (figs. 4 to 15).

\* Several prominent malacologists have recently considered the group (*Isopleura*) including these two divisions, as a class distinct from Gastropoda. I prefer, for the present, to consider the group as a sub-class.

In general, it may be stated that nearly all Gastropoda, except certain terrestrial and fresh-water forms, pass through veliger stages (figs. 4–11, p. 99); that nearly all Bivalvia, except fresh water mussels, pass through veliger stages (figs. 17–19); that the Scaphopoda pass through special forms of veligers (fig. 16); that the Pteropoda all have veliger stages, often with peculiar secondary modifications (figs. 12–15); that the dibranchiate Cephalopoda, so far as known, have an abbreviated development, coincident with large eggs and a large amount of yolk, and that they leave the egg with the general structure of the adult, without passing through a true veliger stage. Terrestrial gastropods, and some fresh-water forms, also have large eggs and abbreviated metamorphoses, without passing through a well marked veliger stage. The littoral genus *Oncidium*, among terrestrial pulmonates, affords exceptions to the rule, as it has a true veliger stage.

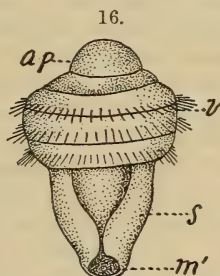


FIGURE 16.—Veliger of *Dentalium*, with well formed bilobed shell (s).

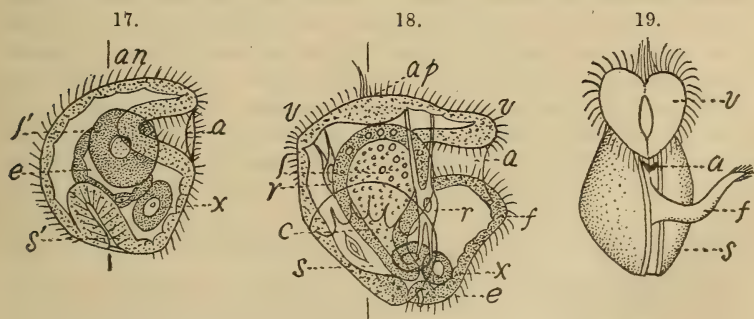


FIGURE 17.—Proveliger of bivalve (*Teredo navalis*), side view.

FIGURE 18.—Subveliger of *Teredo*.

FIGURE 19.—Veliger of mussel (*Dreissena*), ventral view, showing well formed foot (*f*) capable of being used for locomotion and for attachment by secreting a byssus. For explanation of letters, see p. 98.

In the ordinary proveliger stage (fig. 17), the larva of a bivalve, such as a clam or oyster, differs but little in structure from that of a spiral marine gastropod, or from that of a nudibranch gastropod, or a pteropod (fig. 12); nearly all the



organs of the proveligers and subveligers of these diverse groups can be strictly compared, part for part. Their principal differences consist in the form of body; in the shell when it appears, and especially in the degree of development of the velum. This larval locomotive organ may be, as in bivalves, a simple, thickened, ciliated ridge around the cephalic region (fig. 18); it may develop two broad rounded ciliated lobes, as in most gastropods (figs. 6, 9); or these lobes may become subdivided into four or more lobes, as in *Natica* (fig. 10), and certain pteropods.

These molluscan larvæ, in an earlier stage of development, closely resemble the corresponding larvæ of certain annelids; they also resemble in several respects certain adult Rotifera. The first distinctive molluscan organ that appears is the shell-gland (figs. 12, 17, *s'*), which is formed by an invagination, at the posterior or postero-dorsal end.\* Its universal presence in the larvæ, even of such species as never have a shell, is very significant. The digestive system at this time may consist only of a simple cavity (stomodeum) and the mouth (*a*). The latter is situated antero-ventrally; it is usually, but not always, formed from the blastopore.† The anterior or cephalic region (*ap*) is differentiated at an early period, and carries a preoral circle of cilia representing the rudiment of the velum (*v*). The anus (*e*) is nearly always formed somewhat later than the mouth, by an invagination. At first it is usually only a little way back of the mouth. Its completion marks the true veliger stage. The foot begins in the proveliger as a slight ventral protrusion (*f*), between the mouth and anus, and as it grows these two openings are pushed farther and farther apart; they may finally arrive even at opposite ends of the body, as in the bivalves. The shell (*s*), beginning at the shell-gland, appears quite early in the subveliger stage, and soon spreads over much of the body, and at once shows by its form and structure to which class the veliger belongs, for in the subveligers of *Bivalvia*‡ the shell is, from the first, bivalve (fig. 18); in that of the Scaphopoda it is saddle-shaped or sub-tubular (fig. 16, *s*); in that of the Gastropoda it is hemispherical or cup-shaped and usually more or less incurved,§ subspiral, or

\* It is not improbable that the secretion of the shell-gland was used as the first means of adhesion in many primitive forms of cephalopods and gastropods.

† According to the figures and descriptions of observers, the blastopore sometimes becomes the anus, sometimes elongates and then divides to form both mouth and anus, but in much the largest number of groups it forms the mouth alone.

‡ The name *Bivalvia*, given to this group by Linné, should replace the various later and less characteristic names, such as Lamellibranchiata, Pelecypoda, Conchifera, Acephala, etc.

§ The primary form was probably hemispherical or cup-shaped, a form still found in the veligers of many pteropods (figs. 13, 14). The first curvature or incurvature of the shell was probably due to the pulling action of the strong retractor muscles of the velum. This is very evidently the case in pteropod veligers in which the young shell is bent only a little, but precisely in the direction

distinctly spiral (figs. 7, 8, 9); in the Pteropoda\* it is sometimes spiral and sometimes conical or cornucopia-shaped (figs. (13, 14). Therefore some of the fundamental distinctions between these classes are clearly developed in the early veliger stages, at a time when the gills and heart have not appeared, and when the central nervous system is represented only by rudiments of the cerebral ganglions (fig. 13, *n*), and when the foot, itself, has no definite or characteristic form.

These facts naturally lead to the conclusions that all mollusks have been derived from free-swimming forms similar to modern veligers and proveligers, and that each of the great classes, and perhaps some of the subclasses, had already become differentiated while still having veliger-like forms and modes of life, or in other words, that the primitive bivalves, scaphopods, and gastropods, when adult, were all small, free-swimming forms, furnished with a ciliated locomotive organ, similar to the velum of modern veligers. Some of these swimming species may have developed directly a swimming foot adapted to a continued free-swimming existence, and thus the primitive pteropods may have originated. In others the primitive foot may have developed directly into a creeping disk, or into a sucker-like disk for adhesion while resting, from which the transition to a creeping disk would be easy. Many modern veligers (*Natica*, fig. 11, etc.) acquire a well-formed creeping foot, with an operculum, before they lose the velum, so that they can either swim or creep at will. In this way the creeping Gastropoda may have arisen. In the case of the heteropods, which are free-swimming Gastropoda, with the foot in the form of a median fin, we often find a small cup-shaped sucker on the foot, which probably is used for adhesion to floating objects while resting. This may be the survival of a condition that was common among primitive gastropod veligers. Indeed the heteropods, as a group, may be of very ancient origin, and not derived, in comparatively recent times, from normal gastropods, as is often stated. Associated with the remains of other forms of pelagic animals, in paleozoic

of the pull of the retractors (figs. 14, 15, *r*, *r'*), which are here attached far back, near the end of the shell. When they are attached farther forward, the tendency is to cause a stronger curvature, as in gastropod veligers. The primary one-sided and spiral form of the shell is probably due to the inequality in size of the nutritive yolk-masses (figs. 6, 12, 13, *u*, *u*).

\* For my present purposes I prefer to treat the Pteropoda as a distinct class, but yet admit their close relations to the opisthobranchiate gastropods. The latter may have been derived from primitive pteropods, instead of the reverse, as claimed by Pelseneer, who holds that they are a modern group, not earlier than the Tertiary, and derived directly from two different families of living opisthobranchs. In the paleozoic rocks of America there are, however, an abundance of pteropod shells having all the shell-characters, including the peculiar nucleus, present in the common living genus *Styliola* or *Cresets*, even if the *Tentaculites* be not considered as pteropods. There is no good reason for denying the latter.

rocks, certain small shells are found which appear to be true heteropods.\*

It is also easy to believe that adult free-swimming bivalves, with a permanent velum, may have been abundant in the ancient seas. It is even possible that some of the described small and delicate Cambrian bivalves may have been thus furnished. It is not difficult to understand how such forms may have developed a foot suitable for creeping or for adhesion by a sucker or byssus while still retaining the velum, for this still occurs in modern veligers (figs. 11, 19). It is significant that the most primitive of living bivalves (*Nucula*, *Leda*, *Solemya*, etc.) have the foot so modified that it can be used as a very effectual swimming organ. The allied ancient forms may have had a similar foot without losing the velum, and thus there may have been strictly pelagic adult bivalves of considerable size.

The primitive Cephalopoda were probably also derived from veliger-like forms, though no true cephalopod veligers are yet known. It is not difficult to understand how a cephalopod could be derived from a proveliger similar to that of some pteropods and gastropods, by a special development of the foot into prehensile processes around the enlarged head, while the gill-cavity developed most on the ventral side, as in some pteropods. On the other hand, it seems impossible to derive a cephalopod or a bivalve from a creeping chiton-like archetype, such as Lancaster has proposed.

\* Especially the genera *Microceras* and *Cyclura* of the Lower Silurian. Some species referred to the former genus, which I have examined, have a dorsal carina and median slit like species of the modern genus *Atlanta*, which they also resemble closely in size and form.

#### EXPLANATION OF FIGURES 4-15.

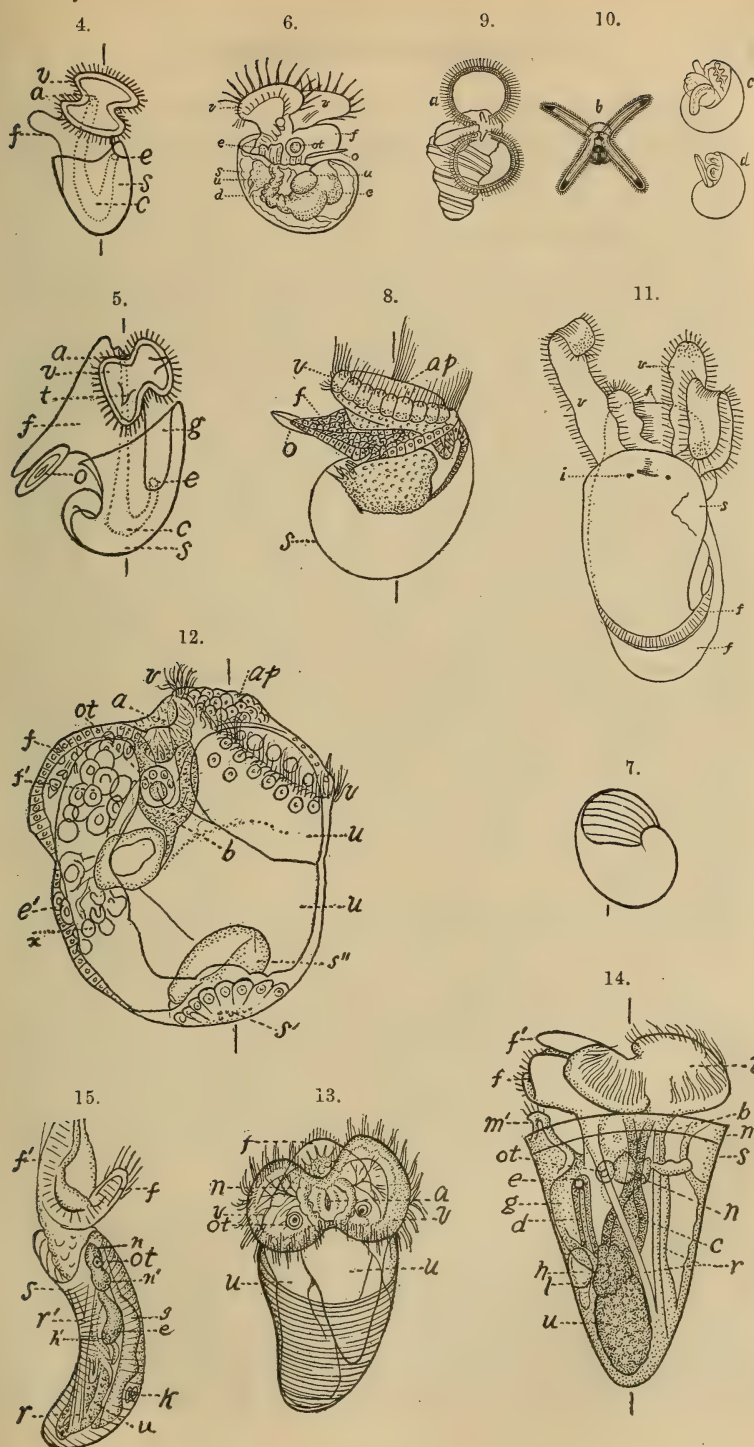
FIGURES 4-11.—Larval gastropods; 4, 5, younger and older veliger stages, diagrammatic; 6, veliger of a nudibranch (*Polycera*) with shell; 7, simple incurved stage of early veliger shell of undetermined species; 8, early veliger of limpet (*Patella*) with similar subspiral shell; 9, mature veliger of *Triforis*, with reversed shell and elongated foot; tentacles and eyes are well formed; 10, veligers of *Natica*, *b*, with four-lobed velum expanded; *c*, *d*, with velum nearly retracted, but showing foot; 11, the same, more enlarged and somewhat older, in the act of crawling, showing a well developed spiral shell, *s*, and a broad creeping foot, *f*, *f*, while the four-lobed velum, *v*, *v*, is still functionally active and capable of being used for swimming (from life).

FIGURES 12-15.—Larval pteropods (after Fol); 12, proveliger of *Cavolina*; 13, subveliger of *Cavolina*; 14, veliger of the same; 15, more advanced young; to show curvature of shell probably due to action of the retractor muscle, *r*, *r'*.

The lettering is the same for all the figures of veligers in this paper (figs. 4-19); *ap*, apical plate; *an*, anterior pole; *a*, mouth; *b*, oesophagus; *c*, stomach; *d*, intestine; *e*, anus; *e'*, its rudiment; *f*, foot; *f'*, epipodium or wings of pteropod; *g*, gill-cavity; *g'*, gill; *h*, heart; *h'*, aorta; *i*, eye; *k*, nephridium; *k'*, its duct; *l*, liver; *l'*, material out of which it is formed; *m*, mantle; *m'*, mantle edge; *n*, cerebral ganglion; *n'*, pleural ganglion; *n''*, pedal ganglion; *o*, operculum; *ot*, otocyst; *r*, *r'*, retractor muscles of velum; *s*, shell; *s'*, shell gland; *s''*, its interior; *t*, tentacle; *u*, *u*, nutritive sacs, or yolk substance; *v*, velum; *x*, anal cells. The short vertical lines at each end indicate the antero-posterior axes of several. All are much enlarged.

The sources of the veliger cuts are as follows: 4, 5, from Gegenbauer; 6, from Lancaster; 7, 9, 10, 11, from nature, by J. H. Emerton; 8, after Patten; 12, 13, 14, 15, after Fol; 16, after Kowalevsky; 17, 18, after Hatschek; 19, after Korschelt and Heider.





FIGURES 4-11.—Veligers of Gastropoda; 12-15, proveligers and veligers of Pteropoda. For explanation, see p. 98.

ART. XIII.—*The Geologic Efficacy of Alkali Carbonate Solution*; by E. W. HILGARD.

[Read at the April meeting of the National Academy, 1896.]

THE effects of carbonated water in the decomposition and the transformation of rocks are well understood, and are usually compared with those of other acid solvents occurring in nature. Among its most important effects are the decomposition of refractory silicates, such as the feldspars and hornblendes, and the dissolution and redeposition of earthy and metallic carbonates. Its effects in connection with the alkalis are much less obvious, and the conditions under which alkali carbonates may be formed and maintained are far less thoroughly understood than in the case of the earthy and metallic compounds. While alkaline mineral waters are comparatively plentiful, the manner of their formation, under the varied conditions in which they are found to exist, is not at all obvious. Such waters, even when hot, are almost always strongly charged with carbonic acid, which is supposed to have extracted the alkalis from their silicate combinations. This at least is the explanation usually given, since according to the ordinary conceptions of the relative "strength" of the mineral acids, it is not readily conceivable that the chlorids or sulphates of the alkali metals should be sensibly decomposed by the action of free carbonic acid, implying the formation of free chlorhydric or sulphuric acids.

The rarity of the occurrence of alkali silicates in natural waters renders the derivation of the alkaline carbonate waters from them a somewhat forced conclusion. A discussion of several hundreds of analyses of well and spring waters showed only three in which alkali silicates were found, while all contained the chlorids and sulphates of the alkalis, usually together with calcic and magnesian carbonates. It is the object of this paper to discuss the possibilities of a much easier mode of formation, which explains both the very frequent occurrence of carbonated alkali waters and the presence of the accompanying salts of neutral reaction.

The rationale of this process of formation of alkali carbonates has been explained in papers heretofore published by me in "Agricultural Science," as well as in the proceedings of the "Deutsche chemische Gesellschaft" for December, 1893. The investigation, made successively in conjunction with A. H. Weber and M. E. Jaffa, from 1887 to 1891, had for its starting point the observation frequently made by me in the analyses of waters, that gypsum crystals are very commonly

observed in evaporation residues of intensely alkaline reaction upon litmus paper. This state of things, so completely contrary to the play of affinities as set forth in our standard books of reference, seemed to call for a special investigation of its cause; which become the more interesting as the alternative presence of alkaline carbonates, sulphates and chlorids in the alkali soils of the arid region, in spots but a few yards apart, seemed to imply a connection with the above facts.

It occurred to me that the presence of an excess of carbonic acid, or of "super-carbonates," might be concerned in the apparent anomaly; since normal alkali carbonates are described as standard precipitants of the earths, even in analytical operations. In looking up the subject in the journals, I found that in 1826 already Brandes (*Schweigger's Journal*, vol. 43, page 156) had called attention to the fact that calcic carbonate is not precipitated from solutions containing only one part in 6,000 to 7,000 of water, as observed by him in the investigation of the noted mineral water of Pyrmont. He moreover states directly, that sodium salts dissolved in that amount of water with calcic carbonate form sodic carbonate. It did not occur to him that the free carbonic gas, so abundantly contained in the Pyrmont water, had any part in the reaction. The matter attracted no further attention at the time; later writers attribute the failure of the calcic carbonate to come down under these conditions to "the solvent effect of the alkali salts."

The next mention of the reaction is made in 1859 by Alexander Mueller of Stockholm. He states that carbonic gas passed into a solution of neutral alkali salts, in which calcic carbonate is suspended, forms so large an amount of alkali carbonate as to render the reaction of the solution alkaline. The wide importance of the reaction, however, did not seem to occur to him at the time.

In investigating the subject I quantitatively followed his precedent; employing solutions of successively greater strength, from one quarter of a gram to a liter up to eight grams, where a critical point seems to have been reached. The compounds used were the sulphates of potassium and sodium; the calcic carbonate was prepared by cold precipitation with ammoniac carbonate. We thus obtain an exceedingly fine precipitate, which readily remains suspended in water, and of which from 5 to 8 grams were used in the experiment, so as to insure an excess. With a rapid current of carbonic gas the reaction is usually complete within forty minutes, a longer continuance producing no additional effect. Examination of the sediment then shows an abundance of gypsum, while the solution is intensely alkaline.

It might be supposed that in this case the difficult solubility of calcic sulphate is a determining factor in the decomposition;



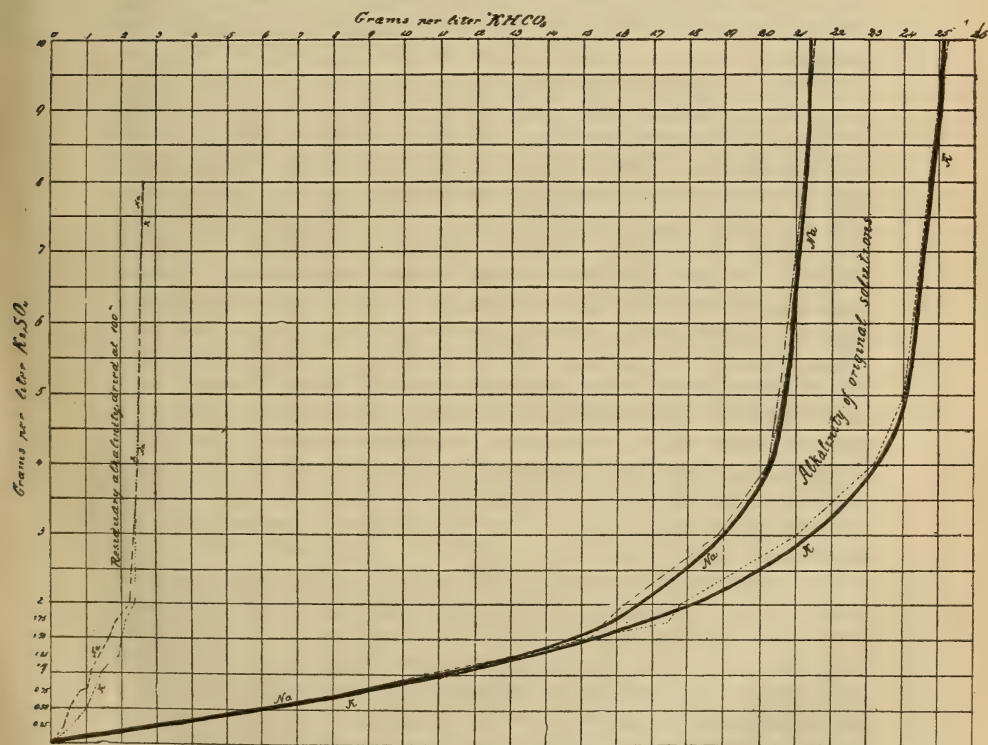
but when, instead of the alkali sulphates, the *chlorid* solutions are employed, the result is qualitatively the same; the highly soluble  $\text{CaCl}_2$  coexisting in solution with the sodic or potassic hydro-carbonate.

Now when we consider the almost universal co-occurrence of the three factors, viz. calcium and magnesium carbonates, alkali chlorides and sulphates, and free carbonic acid in nature, both at the surface and in the geological strata, it is easily seen that this simple process of formation of the alkali carbonates must be of vastly more frequent occurrence than that which presupposes the existence of soluble alkali silicates. The fact that, as stated above, the evaporation residues of such well and spring waters nearly always show an alkaline reaction, is thus explained very simply, upon the easily verifiable supposition that they contain, not the normal salts, but in part at least the super-carbonates, whose presence is compatible with that of soluble earth salts.\*

When solutions prepared artificially as above described, and filtered, are then evaporated hot, the reaction goes back to a considerable extent, earth carbonate and alkali sulphate being again formed. *But no amount of boiling will entirely destroy the alkaline reaction:* as might be expected from the well known fact that in order to obtain the normal carbonate with certainty, it is necessary to use a red heat, and that all alkali carbonates exposed to atmospheric air absorb a small excess of carbonic acid. When, on the other hand, solutions thus prepared are allowed to evaporate spontaneously, at the *ordinary* temperature, the going-back occurs to a very much less extent, and in the case of soda especially the crystalline residue consists largely of "sesqui-carbonate." The curves given on p. 103 show at a glance the transformation of the sulphates of sodium and potassium into carbonates, under the influence of calcic carbonate and excess of carbonic acid in progressively stronger solutions. Corresponding experiments made with magnesian, instead of calcic, carbonate promptly showed that the same reaction occurs with at least equal facility. This renders it evident that the same must be true of many other earthy and metallic carbonates, but only the barium salt has been actually tried thus far, but with the expected result. As our systematic experiments were carried out with calcium carbonate only, the

\* A notable case of the direct formation of alkali carbonates in rock decomposition occurs in the northwest region of the Pacific Coast, where waters containing alkaline carbonates almost alone, with only a trifling amount of silica, issue directly from the crevices of the bare basaltic rock, which of course contains little or no sulphur compounds; but the sulphates become abundant wherever this rock is associated with the later sedimentary deposits. Here, if anywhere, one would have expected to find alkali *silicates* as a direct result of rock decomposition by carbonic acid.

latter is hereinafter always alone mentioned, it being doubtless the most important material in the natural occurrence of the reaction. But magnesian carbonate at least may be always considered as practically included within the same considerations; and while our experiments have for the convenience of the analytical operations been conducted with the sulphates, there can be no doubt that the *chlorids* must be included, although owing to the analytical difficulties encountered in their investigation, it is still uncertain whether (as is probable) the limits of the carbonate formation are narrower than in the case of the sulphates, in which the calcic sulphate formed is partially thrown out of action in the form of gypsum crystals.



*Progressive Transformation of Alkali Sulfates into Carbonates*

(The figures along upper line represent tenths of one per cent.)

The method employed in the determination was to precipitate from the solution saturated with  $\text{CO}_2$ , the calcic carbonate and sulphate by means of alcohol, added until its percentage reached about 65 per cent.; then titrating the filtrate (which is

practically free from lime) with standard acid. The outer curves represent the amount of hydrocarbonate formed in each case, the inner ones that remaining after hot evaporation. While the intervals between the successive points of observation are wider than could be desired, there can be no doubt as to the general outcome. It is seen that up to  $1\frac{1}{2}$  grams per liter, the curves for sodium and potassium almost coincide, within the limits of errors of observation: from that point, however, they rapidly diverge, the weight of the sodium salt formed becoming less than that of the potassium salt, as would be anticipated from the difference in atomic weight. At 8 grams per liter the respective amounts of the two salts formed are almost exactly in the proportion of their molecular weights and so continue to the limit of the experiments (ten grams).

It will also be noted that up to one gram per liter in the case of the potassic salt, and to 8 grams per liter in the case of the sodic, the entire amount of alkali sulphate is transformed into carbonate. Beyond that point there is a rapid decrease in the *proportion* of sulphate transformed; so that at 8 grams per liter only about one-fourth suffers the change, while at the same time the *absolute amount* formed has almost ceased to increase. The existence of this limit prevents this simple mode of producing sodic carbonate from being technically useful, as it would not pay to evaporate such dilute solutions. Nature, however, has, and still continues, to perform this service to humanity in the arid regions, from which Trona, Urao and Kara have for ages been imported into Europe, forming in former times the only source of sodic carbonate. In these crude commercial articles the chloride and sulphate is invariably associated with the carbonate, to a greater or less degree, indicating plainly the process and the materials concerned in its formation.

As to the calcic carbonate: Calcareous rocks are known to exist in the African and Mexican localities from which the respective products (Trona and Urao) are derived. But there is a wider cause for the almost universal presence of the calcic carbonate in the surface formations of the arid regions, which I have discussed elsewhere;\* a fact confirmed by either direct or casual observation of travelers and explorers in those regions, all over the world. The almost universally calcareous nature of the *soils* covering the region west of the Rocky Mountains, irrespective of the nature of underlying rocks or adjacent mountains, has now become a matter of common note.

*Alkali soils.*—The phenomena just discussed afford an insight

\* See Bulletin No. 3, U. S. Weather Bureau, 1892; Wollny's *Forschungen*, etc., 1893; *Annales de la science agronomique*, 1893; and Reports of the California Experiment Station.



into the perplexing alternations in the nature of the soluble salts existing in alkali soils, even in closely contiguous spots; the alkali carbonates predominating in one spot, while in others, not many yards away, sulphates and chlorides are altogether predominant. A detailed discussion shows that the carbonate almost always occurs in the lower, moister and denser soils, while the neutral salts predominate on the higher ground, and in open soils. Moreover, the carbonate always exists in larger relative proportion in the depths of the soil, where at times the carbonate of soda forms the almost exclusive ingredient;\* showing clearly that, wherever in the soil column carbonic acid is continually formed and retained, by fermentative or oxidation processes, the formation of carbonate predominates; while near the surface, under the influence of aëration, the reverse process gains ascendancy.

*The Alkali Carbonates as a geological agency.*—The powerful chemical effects of alkali carbonates upon the rock ingredients hardly require discussion. From the radical results obtained in their fusion with silicates in the laboratory, to the more gentle action exerted by alkaline carbonated mineral waters in dissolving and redepositing silica, whether in the form of sinter or of gold-bearing quartz veins, there is a wide range of possible and probable reactions, less incisive than the former, and more so than the latter, that will readily explain a good many recondite as well as common phenomena of metamorphism as well as of vein formation, without resort to violent hypotheses. Investigation has not yet progressed far enough to teach us what may be the measure and direction of the above reactions under the increase of heat and pressure, which is so common a factor in geological deposits, and which, with one accord, we connect with the phenomena of rock metamorphism. The liquid carbonic dioxide, found inclosed in quartz crystals, suggests forcibly to what extent the intensity of the reactions in which it participates may be carried in the depth of the earth; and how under heavy pressure its mere preponderance of chemical mass may, in the case before us, intensify and multiply the reactions.

Free carbonic acid, impregnating, in presence of earth carbonates, any solution of alkali salts, will form a solvent of amphoteric reaction, both alkaline and acid in its solvent effects; corresponding in the body of the earth to that other amphoteric solvent, the hydrosodic and hydropotassic phosphates, which play so important a part in vegetable and animal bodies. In regard to the formation of deposits of metallic minerals we need but remember the facility with which alkali sulphids are

\* See Bulletin of the Cal. Exp. Station No. 108, "The distribution of the salts in alkali soils"; also Report of the same for 1894-95.

formed and decomposed in presence of metallic sulphids and oxids, and the solvent action so generally ensuing, to appreciate the important part they may play in this connection, especially under the frequent variations of pressure likely to occur in fissures, causing corresponding fluctuations in the amount and nature of the gases present. The almost constant co-occurrence of calcic carbonate in gypsum deposits is exactly parallel to the effect produced by the carbonic gas passing into the magma of alkaline sulphates and calcic carbonate in the fundamental experiment. The frequent paragenetic occurrence of earthy and metallic carbonates and sulphates (or in the case of heavy metals, of sulphids formed by the reduction of the latter) suggests a possible similar origin, more readily intelligible than the action of the solutions of calcic carbonate alone, which is commonly invoked for such transformations as that of anglesite into cerussite, or of blende into smithsonite. In both these cases the alkali carbonates seem much more likely to be an efficient agency, especially in view of their more decided character in the excitation of electrolytic action.

*Physical Effects.*—Scarcely less important than the multifarious chemical effects that may be produced by the superacid alkali-carbonate solutions, are the physical effects which they may and doubtless have exerted upon the consolidation and lithification of sedimentary deposits containing clay. The peculiar "puddling" effect of dilute solutions of sodium carbonate upon clays, to which I first called attention in 1872, is probably one of the most active agencies in converting ancient soils and other clayey alluvium into the compact masses of shales and hardened clays which are specially characteristic of all coal-bearing formations. The potency of this action is especially apparent, at this day, in the alkali lands of the arid regions; where the spots or areas subject to this action of carbonate solutions are seen to be conspicuously depressed below the level of the contiguous alkali-free land, in consequence of the collapse of the floccules usually existing in all soils, and characteristic of all recent alluvial deposits, as a result of the currents and counter-currents under whose influence they have been formed. The soil in such areas often becomes so far consolidated as to resist all efforts at tillage or pulverization, so that even blasting with dynamite will sometimes only throw up large chunks of consolidated soil. The clay hardpan thus formed in the depths even of lands not so heavily impregnated is of a similar nature, and forms one of the most formidable obstacles to the reclamation of such lands. It can in fact be overcome only by the chemical decomposition or transformation of the alkali carbonate into a salt of neutral reaction, such as the sulphate; most readily accomplished by the agency of

calcic sulphate. The puddling effect of dilute carbonate solutions is so striking, so easily brought about, and so permanent when once accomplished, that it should command serious attention as a means for the consolidation of earth dams and fortifications, whose tough resistance to the penetration, whether of water or missiles, would render them effective under conditions under which they would otherwise be altogether insecure. If we imagine the amphoteric solution as imbuing a loose clay deposit, which is then subjected to pressure such as constantly occurs in the formation of geologic strata, the quick consolidation resulting from the destruction of the flocculent structure, and then the collapse by compression; and the subsequent deposition of calcic carbonate, dissolved silica or both, we can easily conceive of the formation of a very substantial rock within (geologically speaking) a very short period of time.

It thus appears that whether viewed from the chemical or physical standpoint, the ready formation of super-acid alkali carbonate solutions by the mutual reaction of neutral alkali salts, calcic, magnesian or generally earthy and metallic carbonates, and free carbonic acid, is likely to throw light upon many intricate problems in chemical geology; so that the further study of this reaction in its complex bearings upon other salts and metallic compounds than those heretofore investigated by us, offer a most promising field for farther research.



ART. XIV.—*An Apparatus for the Rapid Determination of the Surface Tensions of Liquids*; by C. E. LINEBARGER.

I. INTRODUCTORY.

THE essential difference between the gaseous state on the one hand and the liquid and solid states on the other hand is that in liquids there exists a pressure directed towards their interior, while in gases such a pressure seems to be wanting, particularly when the gases are far removed from their point of condensation. This internal pressure is attributed to the mutual attractions of the molecules of bodies, its amount being in inverse proportion to the mean molecular distance. Thus, if the molecules of a portion of matter be comparatively far apart, their reciprocal influences are negligibly small, but, as they come closer and closer together, their attractions become appreciable in the variations shown by gases under certain conditions to the Laws of Boyle and Charles, and eventually, the attractions become so great that the gas condenses into a liquid with its horizontal surface, slight compressibility, etc.

In liquids, the internal pressure is undoubtedly exerted equally in all directions; in crystalline solids, however, its amount may vary with the direction, unless they be isotropic; in colloids, finally, which may be regarded as exceedingly viscous liquids, the internal pressure is the same in all directions.

Although the internal pressure has long been recognized to be of prime importance in the investigation of the nature of liquids, but little that is more than approximately quantitative is known concerning its amount. This is due to the circumstance that as yet no experimental methods have been devised which can give direct determinations of it, since it has been found impossible to connect the interior of a liquid with a manometer without the intervention of its surface. Our quantitative knowledge of the internal pressure is obtained indirectly by assuming theoretical relationships between its amount and some of the properties of liquids (latent heat of vaporization, volume, changes, etc.,) or solutions, which are susceptible of direct measurement. All of these indirect methods agree in assigning to the internal pressure an enormous value, hundreds of atmospheres, at least, under ordinary conditions.

The phenomena displayed in the surface of liquids, the so-called capillary phenomena, are, perhaps, more intimately related to the internal pressure than any other property of liquids. The importance of these capillary phenomena in Nature's happenings does not seem to have always been fully realized. Nearly all interactions of bodies that can be thought

of are surface actions, at least, in part. For example, the solution of a solid in a liquid may be regarded as occurring in two phases: (1) the action of the liquid and solid on each other at the surface resulting in the passing of particles of the solid through the separating surface over into the liquid, and (2) the action between the dissolved particles and the liquid, the effect of which is to bring about their equal distribution throughout all parts of the liquid system; many other examples easily present themselves.

The surface tensions and energies of liquids and solids being of such importance in the elucidation of the nature of liquids and solids in general, it is self-evident that the determination of the values of these constants for as many liquids and solids as possible is very desirable. No experimental methods have yet been devised for the measurement of the surface tensions of solids, and those employed in the investigation of the capillary constants of liquids are generally not capable of giving very accurate results; their degree of accuracy rarely exceeds one part in ten thousand. Furthermore, the apparatus necessary to attain this accuracy requires very careful manipulation in every detail, and a not inconsiderable period of time is needed for each determination. These circumstances stand in the way of the multiplication of data, a study of which may lead to important and far-reaching theoretic results. There is accordingly a demand for a rapid and at the same time accurate method of determining the capillary constants of liquids.

Among the various methods employed in the determination of the surface tension of liquids there is one that undoubtedly meets the requirement of rapidity of execution. Simon,\* the inventor of the method, measured the pressure needed to force bubbles of air out of a capillary tube plunged in a liquid. This pressure he assumed to be equal to the sum of (1) the hydrostatic pressure which the liquid exerts at the mouth of the tube, and (2) to the pressure corresponding to the height to which the liquid would rise in the tube because of its surface tension. This latter assumption is strictly true, however, only in case the form of the issuing bubble of air is identical with that of the meniscus within the tube, and in this circumstance lies the objection to the method, otherwise so simple and rapid.

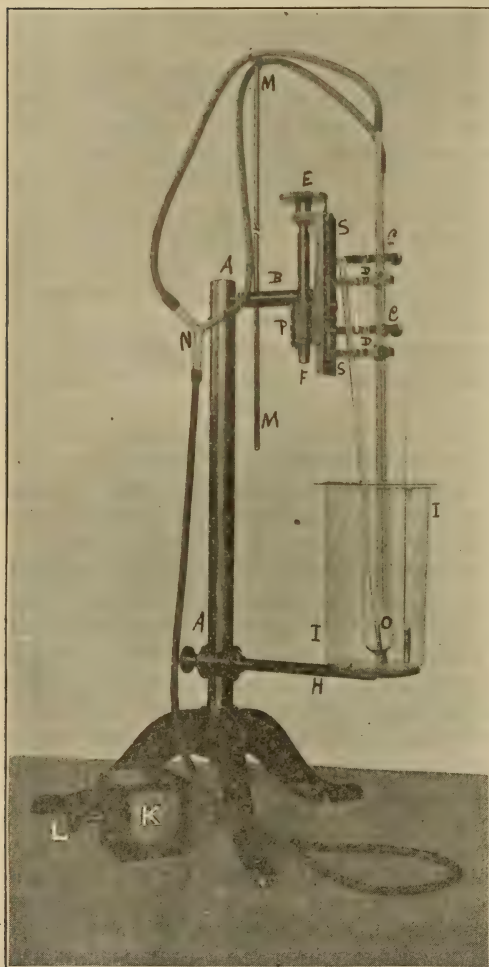
G. Jäger † modified this method by employing two capillary tubes of different bores and measuring the difference of the depths to which they were plunged in a liquid when air forced out of them was at the same pressure. An examination of the apparatus showed that it met the condition of rapidity admira-

\* Ann. de Chim. et de Phys., III, xxxii, p. 1.

† Wien. Ak. Ber. c, p. 245, 1891.

bly and seemed to be capable of a considerable degree of accuracy. The apparatus described below is a modification of the one employed by Jäger.

## II. DESCRIPTION OF APPARATUS.



The apparatus (fig. 1) consists of the following pieces:—a column of brass tubing AA with iron tripod base; a short horizontal arm B, to which is attached a brass gibbed plate SS supporting the capillary tubes by means of the clamps CC and DD, and also the micrometer screw EF; a retort ring AH bearing the beaker II; a compression device consisting of a screw L pressing into a rubber ball K, which is connected by means of rubber tubing and a glass Y-tube N to the upper extremities of the capillary tubes; a vertical rod MM passing through the arm B (to which it may be clamped by a thumb-screw not shown in the figure) and provided with rings to support the rubber tubes connected with the capillary tubes, the lat-

ter being thus relieved of the weight of the former; a test-tube O, into which the capillary tubes pass, supported by the cover of the beaker II; two thermometers, one to take the



temperature of the bath-liquid contained in the beaker, the other that of the liquid undergoing investigation in the test tube O.

Some of these pieces require a more detailed description.

The immovable part of the gibbed plate has a scale fastened along its side divided into fortieths of an inch, while its movable part has a pointer playing over this scale. Back of the gibbed plate is fixed the bearing P in which the screw EF turns; the clamps CC are attached to the fixed portion of the gibbed plate, also another pointer for the milled head of the screw.

The micrometer screw demands a specially detailed description, inasmuch as the accuracy of the results obtainable by the apparatus depend mainly upon the accuracy of its construction. The one I use has forty threads to the inch, is about four inches long, and of good diameter, so as to give absolute motion, the adjustable split-bearing P taking up all lost motion. Great pains were taken in turning it, and I have been unable to detect any irregularities in its construction, indeed, the screw furnished by the makers is even more accurate than is really necessary. The milled head E (about 35<sup>mm</sup> in diameter) is divided into 100 parts, thus giving a direct reading of  $\frac{1}{4000}$  of an inch, and even less than that, since it is easy to estimate fractions of a division.

Three capillary tubes were employed in working with the apparatus :

|   |  |
|---|--|
| A | with a bore of about 1.5 <sup>mm</sup> . |
| B | " " " " " 0.5 "                          |
| C | " " " " " 0.1 "                          |

From the nature of the method it is not at all necessary to know the exact dimensions of the tubes; all that is required is that the bore be approximately circular and the edges sharp. To prepare the capillary tubes, a stock of tubing is examined and tubes of the desired dimensions selected. Pieces are broken off from these tubes until it is found that the ends present plane surfaces perpendicular to the axis of the tube. If the clamps happen to be too large for the tubes, a filling of sheet lead may be employed.

The liquid serving as bath, and contained in the beaker, may be water or glycerine; it is heated by means of a Bunsen burner and kept in motion by means of a stirrer (not shown, however, in the figure). Besides this kind of a bath, much use was made of a vapor jacket, for keeping the temperature uniform during a determination. The test-tube O was fitted into a considerably larger tube by means of a cork through a second perforation of which passed a long glass tube, acting as a condenser. On boiling liquids or mixtures of liquids in the

larger tube, these vapors rise and heat the inner tube with its contents to a desired constant temperature for any length of time.

### III. METHOD OF MAKING A DETERMINATION.

The first thing to do in using the apparatus is to get the lower extremities of the two capillary tubes at the same level. This may be accomplished in the following simple manner. A spirit-level is placed upon a piece of plate glass, which in turn is set upon the support H at the required height, and levelled. The pointers of the side-scale, as well as of that on the screw head, are set at zero, the tubes allowed to rest freely upon the plate glass, and then clamped in position. While this way of fixing the tubes answers well enough for the initial adjustment of the apparatus, it is not sufficiently accurate to insure their being replaced in the same position, if, from any cause, they become displaced. Indeed, it is not at all certain that the tubes are at the same level to within  $0.1\text{ mm}$ , when adjusted in the above manner; yet this degree of accuracy is entirely sufficient for the first adjustment, and by the use of a standard liquid it will be shown how they can afterwards be gotten into the same position to within  $0.01\text{ mm}$ .

The test-tube has a mark scratched on its side, which indicates the volume of liquid that is to be taken for a determination of its capillary constant, it having been found that differences in the distance between the surface of the liquid and the orifices of the tubes have some influence upon the readings of the instrument.\* The volume of the liquid may be as small as a couple of cubic centimeters, if a small test-tube be used; generally, however, it is advisable to employ from five to ten cubic centimeters. The test-tube is filled with the liquid under examination to this mark and the tube suspended in the bath. The beaker is placed upon a piece of asbestos board or wire gauze, set upon the retort ring, which is raised until the capillary tubes are close to the bottom of the test-tube. A thermometer is introduced into the liquid, and the bath-liquid stirred, so as to insure uniformity of temperature. The mode of procedure is essentially the same when a vapor jacket is employed. The rapidity with which the liquid undergoing investigation takes on the temperature of the bath may be hastened by blowing bubbles up through it by compression of the air in the rubber ball K.

When the temperature of the liquid is the same as that of

\* This influence is, however, but slight. Readings with ether were found to differ by only  $\frac{1}{100}$  of an inch, when the differences between the free surface of the liquid and the lower extremities of the capillary tubes differed by more than four inches.

the bath, the movable tube, preferably the one with the smaller bore, is raised by turning the screw. This may be done rapidly while bubbles are being forced out of the larger tube every second or so. At a certain point, bubbles may cease to issue from the larger tube and commence to come from the smaller one, an indication that the correct adjustment has been passed. The screw is now turned very cautiously in the opposite direction until bubbles issue at about the same time from both tubes. The final adjustment is generally best made as follows:

The air is compressed *very slowly* until it has arrived just at the orifices of both tubes. The pressure is then not increased further, and, as a rule, it will be observed that, if the adjustment is perfect, bubbles will issue of their own accord from both the tubes in a second or so; sometimes one of the bubbles lies a little behind the other. The success of the operation depends upon the *steady* and *gradual* compression of the air; if this be subjected to abrupt or irregular changes of pressure, not inconsiderable errors may be committed. It is advisable to make at least two readings, one when the narrower tube is being lowered, the other when it is being raised; indeed, the readings can be made so rapidly that it is a good plan to take a half dozen or so, the tube being moved alternately up and down.

#### IV. DISCUSSION OF SOURCES OF ERROR IN APPARATUS.

In the determination of the capillary constants by means of the apparatus described in the preceding sections, measurements of three kinds have to be made, viz., measurements of specific gravity, of temperature, and of the distance between the lower extremities of the capillary tubes. We pass to the discussion of the errors inherent in each.

I. The determination of the surface tension by any of the direct methods such as measuring the height to which liquids rise in capillary tubes, etc., cannot be said on an average to be accurate to more than one part in two thousand and only in exceptional cases to one part in ten thousand. On the other hand, the accuracy of a specific gravity determination can easily attain one part in ten thousand and in many cases to even one part in a hundred thousand. In the formula to be communicated in the following section, it will be seen that the influence of the specific gravity upon the value of the capillary constant is not very great, so that a determination of the specific gravity to one part in two thousand is perhaps sufficiently accurate for our purposes, although it is of course better to be sure of the fourth decimal place. We may con-



clude, then, that the accuracy of a determination of the specific gravity of a liquid, whose surface tension is to be ascertained, may be counted perfect, if it be made to within one part in two thousand.

II. For temperatures between  $0^{\circ}$  and  $50^{\circ}$ , it is an easy matter to keep the temperature of even such a simple bath as the one given in figure I constant to within  $0^{\circ}\cdot05$  long enough to adjust the apparatus and make several readings. By the use of larger baths, or better still, of vapor jackets, the temperature can be kept sufficiently uniform for the investigation at different temperatures of most liquids. As a variation of temperature amounting to  $0^{\circ}\cdot1$  changes but little the readings of the apparatus, it may be allowed that the temperature is, for the purposes of this investigation, negligible.

III. The possible error that may be committed in the readings of the apparatus can best be judged by considering the readings themselves. A number of series of readings for different liquids at various temperatures are accordingly given just as they were taken directly from the apparatus. These readings are not to be taken as material for the calculation of the surface tensions of the liquids, as in some cases they do not represent the true distances between the lower extremities of the capillary tubes, the position of these having been altered purposely several times. The unit of a reading is a fortieth of an inch.

Nitroethane at  $16^{\circ}\cdot95$   
Tubes A and B.

23·27  
23·26  
23·28

Nitroethane at  $46^{\circ}\cdot6$   
Tubes A and B.

21·23  
21·26  
21·21

Nitromethane at  $24^{\circ}\cdot5$   
Tubes A and B.

24·28  
24·26  
24·23  
24·25  
24·29  
24·26  
24·26

Nitromethane at  $41^{\circ}\cdot5$   
Tubes A and B.

22·86  
22·87  
22·80  
22·81  
22·85

Benzene at  $20^{\circ}\cdot0$   
Tubes A and B

22·86  
22·88  
22·85  
22·86  
22·87

Benzene at  $20^{\circ}\cdot5$   
Tubes A and B.

30·55  
30·54  
30·49  
30·56  
30·55

|                        |                            |
|------------------------|----------------------------|
| Toluene at 25°·0       | Toluene at 46°·6           |
| Tubes A and B.         | Tubes A and B.             |
| 24·42                  | 22·65                      |
| 24·44                  | 22·63                      |
| 24·41                  | 22·62                      |
| 24·40                  | 22·63                      |
| 24·43                  | 22·64                      |
|                        | 22·64                      |
|                        | 22·66                      |
| Another series made    | 22·64                      |
| ten days later.        |                            |
| 24·43                  |                            |
| 24·45                  |                            |
| 24·42                  |                            |
| 24·43                  |                            |
| 24·45                  |                            |
| Methyl Nitrate at 0°·2 | Carbon Bisulphide at 19°·5 |
| Tubes A and B.         | Tubes A and B.             |
| 18·29                  | 19·35                      |
| 18·28                  | 19·32                      |
| 18·25                  | 19·30                      |
| 18·26                  | 19·33                      |
| 18·28                  | 19·34                      |
| Ethyl Ether at 0°·1    | Ethyl Ether at 25°·0       |
| Tubes A and B.         | Tubes A and B.             |
| 17·90                  | 13·55                      |
| 17·92                  | 13·53                      |
| 17·92                  | 13·52                      |
| 17·95                  | 13·54                      |
| 17·93                  |                            |
|                        | Another series made        |
|                        | over a month later.        |
|                        | 13·54                      |
|                        | 13·55                      |
|                        | 13·53                      |
| Toluene at 78°·4       | Monochlorbenzene at 77°·8  |
| Tubes B and C.         | Tubes B and C.             |
| 24·73                  | 23·34                      |
| 24·77                  | 23·38                      |
| 24·75                  | 23·32                      |
| 24·71                  | 23·35                      |
| 24·74                  | 23·34                      |
| Ethyl Iodide at 25°·0  | Ethyl Alcohol at 51°·0     |
| Tubes A and B.         | Tubes A and B.             |
| 8·89                   | 18·65                      |
| 8·87                   | 18·62                      |
| 8·88                   | 18·64                      |
| 8·88                   | 18·61                      |
| 8·87                   | 18·63                      |
| Another series made    |                            |
| twenty days later.     |                            |
| 8·87                   |                            |
| 8·86                   |                            |
| 8·88                   |                            |

Water at 40°·0  
Tubes A and B.

77·10  
77·13  
77·14  
77·09  
77·11  
77·16  
77·13  
77·12

Water at 20°·0  
Tubes A and B.

76·09  
76·13  
76·10  
76·16  
76·23  
76·14  
76·16  
76·18  
76·15

Another series made  
a fortnight later.

76·12  
76·18  
76·21  
76·13  
76·19  
76·14  
76·18

These series of numbers have been taken from my notebooks almost at random, and are but a small fraction of the number of readings I have made. They show that for most liquids differences in the readings amounting to more than  $\frac{1}{800}$  of an inch seldom occur, and when a series of readings are made and their average taken, the error almost vanishes. Only in the case of water were greater differences of readings observed; yet, since water has such a large capillary constant, the error committed is very slight. It was observed that the nearer the extremities of the capillary tubes were, and, consequently, the smaller the numerical value of the reading, the more concordant were the readings.

While the three sources of error just discussed seem to be almost negligible, there is another inherent, not in the apparatus, but in the method, which stands seriously in the way of obtaining reliable absolute determinations of the surface tensions of liquids. This source of error lies in the determination of the "apparatus constant," which may vary from one liquid to another. A more detailed discussion of it will be given in the next section, after the way in which the "apparatus constant" is determined is described (p. 122).

## V. CALCULATION OF RESULTS.

Having now shown the degree of accuracy attainable in the readings of the apparatus under discussion, I will pass to the consideration of the manner in which the results obtained by this indirect method may be converted into those arrived at by



direct methods. As stated above, two things besides the temperature are measured in this method: (1) the specific gravity of the liquid taken, and (2) the vertical distance between the lower ends of the two capillary tubes when air under the same pressure issues in synchronous bubbles from their orifices. It is not difficult to determine the specific gravity to within  $\frac{1}{100,000}$ , although an accuracy of  $\frac{1}{2,000}$  is quite sufficient. The distance between the ends of the two tubes can be measured to about a hundredth of a millimeter, except in the case of water where the degree of accuracy of measurement is only within a tenth of the same unit of length. It is now our task to pass from the data obtained from measurements of these quantities to the capillary constants measured in degrees per centimeter.

Inasmuch as our knowledge of the form of the bubbles just on the point of issuing from the orifices of the capillary tubes is not at all precise, there appears to be no immediate way of finding a relation on theoretical grounds between the data furnished by this indirect method and those given by direct methods. Jäger (loc. cit.) obtained the relationship employed by him in the following manner: "Wie sich unsere Annahme für die Formulirung des Einflusses, welchen die Röhrenweite auf den bewussten capillaren Druck hat, als richtig erwies, so zeigt sich, wie wir später sehen werden, dass es vollständig genügt, wenn wir

$$\alpha F(s) = \alpha(1 + \beta s)^*$$

setzen, wohin  $\beta$  eine Constante bedeutet, die sich ebenfalls leicht ermitteln lässt, wenn zwei Flüssigkeiten, deren  $\alpha$  und  $s$  bekannt sind, zu Gebot stehen. Verwenden wir nämlich zu unseren Messungen stets dieselben beiden Capillarröhren, so wird für die eine Flüssigkeit die Gleichung (1)

$$\alpha(1 + \beta s) \phi(r \cdot r') = hs,$$

für die zweite

$$\alpha(1 + \beta s') \phi(r \cdot r') = h's'$$

somit

$$\frac{\alpha(1 + \beta s)}{\alpha'(1 + \beta s')} = \frac{hs}{h's'}.$$

Aus dieser Gleichung kann der Werth von  $\beta$  ermittelt werden, da alle übrigen in ihr vorkommenden Grössen bekannt sind."

In order to obtain the value of  $\beta$ , he made use of Brauner's† and Wolf's‡ directly determined data for water and ethyl ether. By transforming the equation immediately preceding into

\*  $\alpha$  = Capillary constant;  $s$  = Specific gravity.

† Pogg. Ann. 70, p. 515.

‡ Pogg. Ann. 70, p. 575.

$$a = \frac{a'hs(1+\beta s')}{h's'(1+\beta s)},$$

he obtained therefrom on putting

$$\frac{a'(1+\beta s')}{h's'} = c,$$

$$a = c \frac{hs}{1+\beta s} :$$

and substituting for specific gravity =  $s$ , the specific volume

=  $v = \frac{1}{s}$ , he finally obtained

$$a = c \frac{h}{v+\beta},$$

an equation used throughout his work in transforming his results.

It is hardly necessary to mention that the degree of accuracy which can be attributed to an indirect method of measuring a physical constant of Nature depends upon the accuracy of the results obtained by direct methods; hence, the importance of choosing the most exact directly determined data for the calibration of an indirect method. Ramsay and Shields\* have elaborated the method of measuring the heights to which liquids rise in capillary tubes, and have carried out series of determinations of the capillary constants of various liquids in contact only with their own vapor and glass, which are justly regarded as of the greatest trustworthiness, and may be confidently taken as standards.

If Jäger's equation,

$$\frac{a(1+\beta s)}{a'(1+\beta s')} = \frac{hs}{h's'},$$

be correct, it ought to be possible to obtain the same value of  $\beta$ , when the data for  $a$  and  $a'$ ,  $s$  and  $s'$ , and  $h$  and  $h'$  are taken for any pair of liquids. On carrying out the calculations, however, I found that the values of  $\beta$  varied considerably for different pairs of liquids, when the data given by Ramsay and Shields (loc. cit.) were taken for the specific gravities and capillary contents, and the readings of my apparatus for the differences of level between the extremities of the two capillary tubes. Furthermore, it was found that, if  $\beta$  and  $c$  be calculated for any two liquids, and then from the equation

$$a = c \frac{hs}{1+\beta s}$$

\* Zeitschr. f. phys. Chem., xii, p. 433, 1893.

the value of  $a$  be deduced for a third liquid, differences between the values thus obtained and those communicated by Ramsay and Shields (*loc. cit.*), amounting to as much as ten per cent., were obtained in some cases, although once in a while a pretty good correspondence was observed. Jäger's equation appears to be merely approximate and does not stand a severe scrutiny. Jäger himself seems to find the justification of his formula in its yielding results corroborative of certain theoretical views he advances, and in the agreement between his observed values and those calculated for the same temperatures by means of temperature-coefficients; but as the temperature-coefficients were derived from his own data, which rarely differ by more than five per cent. from those given by Ramsay and Shields (*loc. cit.*), and as he does not attain a much closer correspondence than that between his observed and calculated values, the correctness of the formula does not seem to be any the better established.

It accordingly became peremptory to devise another formula, which should be in better agreement with Ramsay and Shields' measurements. But here a difficulty arose. Ramsay and Shields determined the capillary constants of liquids when freed from air; the liquids were in contact only with their own vapor and glass. There is no doubt but that the surface tensions of liquids can be accurately measured only when no air is present, if the method consisting in the measurement of the rise in capillary tubes be employed. R. Schiff\* had already made this observation before Ramsay and Shields. Just what influence the presence of air has upon the capillarity of liquids we do not know; the greater or less volatility of a liquid makes the degree of dilution of the air in contact with its surface correspondingly greater or less. In the apparatus described in this paper, the liquid under examination is saturated with air, and the pressure of the air varies with the density of the liquid. The difficulty at issue lies in the question as to whether the indirect determinations made with liquids in contact with air are comparable to more than a gross approximation with those obtained by the direct method as employed by Ramsay and Shields (*loc. cit.*). This difficulty seemed at first insurmountable, but, finally, a simple relation was discovered, which shows an excellent correspondence between Ramsay and Shields' data and mine.

The relation in question is

$$(A) \quad \gamma = chs + s^2,$$

where  $\gamma$  represents the capillary constant in dynes per centimeter,  $c$ , the "apparatus constant,"  $h$ , the distance between the

\* Lieb. Ann. cexxxiii, p. 47.



ends of the tubes, and  $s$ , the specific gravity. The value of the constant was obtained in the following way. The data for  $\gamma$  and  $s$  were taken from Ramsay and Shields (*loc. cit.*) and Ramsay and Aston's papers, and those for  $h$  from my own measurements. These were set in equation (A) and the value of  $c$  calculated therefrom. The greatest pains were taken in the purification of the liquids examined, so that they very probably had the same properties as those used by the investigators just named. The data and results of the calculations are given in Table I for the tubes A and B, and in Table II for the tubes B and C.

TABLE I.

Values of "Apparatus Constant" for Tubes A and B.

| Names of Liquids.       | T    | $s$    | $\gamma$ | $h$   | $c$   |
|-------------------------|------|--------|----------|-------|-------|
| Water .....             | 20°0 | 0.9984 | 70.72    | 55.60 | 1.248 |
| " .....                 | 36°0 | 0.9958 | 69.10    | 54.85 | 1.247 |
| " .....                 | 40°0 | 0.9923 | 67.50    | 53.90 | 1.245 |
| Methyl Alcohol .....    | 20°0 | 0.7905 | 23.03    | 23.16 | 1.227 |
| Ethyl " .....           | 20°0 | 0.7900 | 22.03    | 21.97 | 1.236 |
| Acetone .....           | 16°8 | 0.7798 | 23.35    | 22.95 | 1.238 |
| " .....                 | 46°4 | 0.7656 | 19.68    | 20.00 | 1.250 |
| Ethyl Ether .....       | 20°0 | 0.8143 | 16.49    | 17.91 | 1.245 |
| " .....                 | 30°0 | 0.7000 | 15.27    | 16.87 | 1.252 |
| Ethyl Iodide .....      | 19°1 | 1.937  | 30.00    | 10.88 | 1.248 |
| Carbon Bisulphide ..... | 9°7  | 1.2773 | 32.73    | 19.90 | 1.224 |
| Benzene .....           | 11°2 | 0.8871 | 29.21    | 25.86 | 1.239 |
| " .....                 | 46°0 | 0.8500 | 24.71    | 22.75 | 1.241 |
| Chlorbenzene .....      | 9°5  | 1.1182 | 33.71    | 23.46 | 1.238 |
| " .....                 | 45°6 | 1.0795 | 29.30    | 21.25 | 1.227 |
| Toluene .....           | 15°2 | 0.8682 | 28.18    | 25.21 | 1.253 |
| " .....                 | 46°6 | 0.8380 | 24.60    | 22.65 | 1.259 |

Average = 1.243

TABLE II.

Values of "Apparatus Constant" for Tubes B and C.

| Names of Liquids.  | T    | $s$    | $\gamma$ | $h$   | $c$   |
|--------------------|------|--------|----------|-------|-------|
| Acetone .....      | 16°8 | 0.7998 | 23.35    | 27.72 | 1.023 |
| " .....            | 46°4 | 0.7656 | 19.68    | 24.22 | 1.029 |
| Chlorbenzene ..... | 45°6 | 1.0795 | 29.30    | 25.71 | 1.014 |
| " .....            | 77°8 | 1.0444 | 24.65    | 23.38 | 1.011 |
| Ethyl Ether .....  | 20°0 | 0.7143 | 16.49    | 22.08 | 1.036 |
| Benzene .....      | 11°2 | 0.8871 | 29.21    | 31.44 | 1.019 |
| " .....            | 46°0 | 0.8500 | 24.71    | 27.86 | 1.013 |
| Toluene .....      | 15°2 | 0.8682 | 28.18    | 30.60 | 1.032 |
| " .....            | 46°6 | 0.8380 | 24.60    | 27.75 | 1.028 |
| " .....            | 78°4 | 0.8080 | 20.93    | 24.75 | 1.014 |

Average = 1.022

A glance at the tables shows that the "constants" are indeed quite constant. In Table I, the average of the numbers in the last column is 1.243; the greatest variation on one side is 0.019 for carbon bi-sulphide at 9°·7, and on the other side, 0.016 for toluene at 46°·6. Generally, the differences from one liquid to another are not larger than they are for the same liquid from one temperature to another. Likewise, in Table II, the average value of the constant is 1.022, with differences of 0.014 for ether at 20°·0 on the one hand, and 0.011 for chlorbenzene on the other.

Introducing  $c=1.243$  from Table 1 and  $c=1.022$  from Table II into equation (A), and treating  $\gamma$  as the unknown quantity, I calculated the capillary constants to be those given in Tables III and IV, respectively, beside which are placed the corresponding data by Ramsay and Shields (*loc. cit.*) and Ramsay and Aston (*loc. cit.*)

TABLE III.

Comparison of Capillary Constants for Tubes A and B.  $c=1.243$ .

| Names of Liquids.       | T     | $\gamma$<br>$\gamma=chs+s^2$ | $\gamma'$<br>Ramsay and Shields. | $\gamma-\gamma'$ |
|-------------------------|-------|------------------------------|----------------------------------|------------------|
| Water .....             | 30°·0 | 68.82                        | 69.10                            | -0.28            |
| " .....                 | 40°·0 | 67.42                        | 67.50                            | -0.08            |
| Methyl Alcohol .....    | 20°·0 | 23.39                        | 23.03                            | +0.36            |
| Ethyl " .....           | 20°·0 | 22.17                        | 22.03                            | +0.14            |
| Acetone .....           | 16°·8 | 23.34                        | 23.35                            | -0.01            |
| " .....                 | 46°·4 | 19.59                        | 19.68                            | -0.09            |
| Ethyl Ether .....       | 20°·0 | 16.42                        | 16.49                            | -0.07            |
| " " .....               | 30°·0 | 15.18                        | 15.27                            | -0.09            |
| Ethyl Iodide .....      | 19°·1 | 29.90                        | 30.00                            | -0.10            |
| Carbon Bisulphide ..... | 9°·7  | 33.22                        | 32.73                            | -0.49            |
| Benzene .....           | 11°·2 | 29.31                        | 29.21                            | +0.10            |
| " .....                 | 46°·0 | 24.75                        | 24.71                            | +0.04            |
| Chlorbenzene .....      | 9°·5  | 33.86                        | 33.71                            | +0.15            |
| " .....                 | 45°·6 | 29.68                        | 29.30                            | +0.38            |
| Toluene .....           | 15°·2 | 27.96                        | 28.18                            | -0.22            |
| " .....                 | 46°·6 | 24.25                        | 24.60                            | -0.35            |

TABLE IV.

Comparison of Capillary Constants for Tubes B and C.  $c=1.022$ .

| Names of Liquids.  | T     | $\gamma$<br>$\gamma=chs+s^2$ | $\gamma'$<br>Ramsay and Shields. | $\gamma-\gamma'$ |
|--------------------|-------|------------------------------|----------------------------------|------------------|
| Acetone .....      | 16°·8 | 23.32                        | 23.35                            | -0.03            |
| " .....            | 46°·4 | 19.64                        | 19.68                            | -0.04            |
| Chlorbenzene ..... | 45°·6 | 29.56                        | 29.30                            | +0.26            |
| " .....            | 77°·8 | 26.01                        | 25.66                            | +0.35            |
| Ethyl Ether .....  | 20°·0 | 16.42                        | 16.49                            | -0.07            |
| Benzene .....      | 11°·2 | 29.28                        | 29.21                            | +0.07            |
| " .....            | 46°·0 | 24.88                        | 24.71                            | +0.11            |
| Toluene .....      | 15°·2 | 27.93                        | 28.18                            | -0.25            |
| " .....            | 46°·6 | 24.46                        | 24.60                            | -0.14            |
| " .....            | 78°·4 | 21.09                        | 20.93                            | +0.16            |

It is at once apparent that only in several instances the differences between Ramsay and Shields' results and mine amount to more than a few tenths of a per cent., and in some cases the agreement is as good as perfect. Moreover, the differences that are found are very nearly the same when either pair of tubes is employed; this indicates that the differences are due to the possible differing degrees of purity in the liquids employed by each of us rather than to a fault in the apparatus itself. However that may be, the data show that it is possible to obtain with the apparatus results which, by means of the formula (A), are comparable with those obtained by Ramsay and Shields (*loc. cit.*). One cannot withstand the temptation to quote Jäger's words (*loc. cit.*) ". . . unsere Methode ist vollständig geeignet, richtige Resultate zu ergeben. Fasst man noch die leichte, sichere und wenig Zeit beanspruchende Handhabung, welche unser Apparat erfordert, ins Auge, so wird man wohl leicht zur Überzeugung gelangen, dass unter den gegenwärtigen Methoden für den praktischen Gebrauch kaum eine bessere zu finden sein dürfte." As to what pertains to the experimental handling of the apparatus, my experience with it permits me to subscribe to the above. But a restriction has to be made in regard to the conversion of the indirect results furnished by it into direct ones. Jäger's formula has been shown above to be only approximately correct, and the one which I propose has but an empirical basis. Although it has been found to stand the test of comparison with ten liquids of different properties, when two sets of tubes were employed, it is not allowable to claim that it will furnish accurate results for any liquid whatsoever. In other words, the instrument cannot be depended upon to give absolute data, as the "apparatus constant" may differ from liquid to liquid. Still its usefulness is but slightly impaired by that circumstance. There is a vast amount of work to be done in the field of solutions, in which the method can yield excellent results. Here the measurements can be considered to be more correct, since in work with solutions the "apparatus constant" can be determined specially for the solvent. Among some of the problems that may be investigated by means of the method, mention may be made of the following: the superficial tensions of saturated solutions in contact with the solid substance can be very well determined even when the solutions are quite concentrated, and it is likely that a knowledge of this property of solutions will enable us to get at the molecular masses of solids: also, the molecular masses of liquids can be determined very rapidly by the method.

The apparatus described above was made by Walmsey, Fuller and Co. of Chicago, and has proven satisfactory in every particular; the makers inform me that they can now furnish the apparatus provided with a micrometer screw divided according to the metric as well as English system.



ART. XV.—*On Northupite; Pirssonite, a new mineral; Gaylussite and Hanksite from Borax Lake, San Bernardino County, California; by J. H. PRATT.*

#### INTRODUCTION.

THE minerals to be described in this paper are from the remarkable locality of Borax Lake, San Bernardino County, California. They were brought to the author's notice, in the fall of 1895, by Mr. Warren M. Foote of Philadelphia, who sent one of them, the northupite, together with some of the associated minerals, to the mineralogical laboratory of the Sheffield Scientific School, for chemical investigation. About the same time Mr. C. H. Northup of San José, Cal., sent some minerals from the same region to Prof. S. L. Penfield. Among them, gaylussite, hanksite and a third mineral, which has proved to be a new species, were identified. These same minerals were also observed among the specimens sent by Mr. Foote. Mr. Northup, in his letter of transmittal, stated that he had carefully saved all of the crystals of the new mineral, having observed that they were different from gaylussite in habit, and that he believed they would prove to be a new and interesting species.

Both Mr. Northup and Mr. Foote have thus most generously furnished material for this investigation, and the former has also supplied valuable information concerning the locality and mode of occurrence of the minerals. The author, therefore, takes great pleasure in expressing his thanks to both of these gentlemen for the services they have rendered.

In addition to the investigation of northupite and the new mineral, some interesting data concerning hanksite and gaylussite have also been obtained.

*Occurrence.*—The Borax Lake region has already been described by De Groot\* and Hanks† and therefore only a brief description is necessary in this article.

This alkali lake, or better alkali marsh, is situated in the northwestern corner of San Bernardino County near the Inyo County line and is 72 miles from Mojave, the shipping point for that district. Borax Lake proper is a small basin about one mile and a half in length by half a mile wide, separated by a narrow ridge from a larger basin, which is about ten miles long and five miles wide, known as "Dry Lake," "Alkali Flat," "Salt Bed" and "Borax Marsh." The appropriateness of these names is very apparent, for the marsh is really a dry

\* Report State Min. of Cal. 1890, p. 534.

† This Journal, xxxvii, p. 63, 1889.

lake, partly filled up with salt, borax, alkali, mud and volcanic sand. During the wet seasons a little water accumulates, but it remains only a short time and is never over a foot or two deep, while in most places it is not more than two or three inches. In the smaller basin, however, the water stands considerably longer. The larger basin is somewhat lower than the other, the narrow ridge referred to above preventing the waters of the smaller basin from flowing into it.

At the present time, borax is the only product manufactured from the minerals of the locality, and it is from the smaller basin and the narrow ridge that most of it is obtained. Tincal, or native borax, has been found in crystals to a depth of 450 feet, which is as deep as explorations with drills have penetrated. "Crude borax" is described by Mr. Northup as found on the surface of the higher parts of the lake, in a condition resembling burnt bone. Underlying this is a very hard, uneven deposit of different salts, which is generally not disturbed. The crude borax is collected only to a depth varying from two to eight inches, although the original thickness is much greater. In about four years, the efflorescence of borax forms again, the solution being drawn up by capillary attraction and leaving the bone-like deposit on evaporation. Most of the borax is obtained from this crude material, although some is obtained by the evaporation of the natural solution of borax in the lake water.

The minerals described beyond were found while exploring the underlying formations, and were obtained by Mr. Northup after carefully working over the tailings or debris from the borings.

The minerals associated with the borax at this region are, according to Hanks,\* sulphur, gold, cerargyrite, embolite, halite, anhydrite, thenardite, celestite, glauberite, gypsum, calcite, dolomite, trona, gaylussite, natron, hanksite, colemanite, tincal, soda niter and hydrosulphuric acid. To this list sulphohalite, northupite and the new mineral to be described in this paper must be added. Of the foregoing, colemanite,† hanksite,‡ and sulphohalite § were first derived from this locality.

#### *Northupite.*

A preliminary description of this mineral has been given by Mr. Warren M. Foote.¶ According to information received

\* This Journal, xxxvii, p. 66, 1889.

† Bull. Cal. Acad., No. 2, Jan., 1885, and Zs. Kr. 10, p. 179, 1884.

‡ This Journal, xxx, pp. 133 and 136, 1885, also xxxvii, p. 63, 1889.

§ Ibid., xxxvi, p. 463, 1888.

¶ Proceedings of the Acad. of Nat. Sci. Phil., Sept. 1895, and this Journal, 1, p. 480, 1895.

from Mr. Northup, it has been found in only one boring, known as the "New Well," and was probably formed in a stratum of clay, about 450 feet below the surface. With two exceptions, northupite has been observed only in detached crystals, Mr. Foote having in his possession a single specimen showing two octahedrons of northupite attached to a crystal of the new mineral, pirssonite, to be described beyond, and a similar specimen being in the Brush collection.

*Physical properties.*—The crystallization is isometric, the octahedron being the only form observed. The crystals vary in size from less than a millimeter to rarely a centimeter in diameter. There is no apparent cleavage, but the crystals, which are extremely brittle, break with a distinct conchoidal fracture. The luster on fractured surfaces is decidedly vitreous. The hardness is between 3·5 and 4. The specific gravity was obtained by floating the crystals in methylene iodide diluted with methyl iodide and was found to be 2·380. The pure material is colorless, but owing to impurities the color of the crystals, as stated by Foote, varies from dirty white, pale yellow and greenish gray to dark brown. The impurities are probably clay or organic matter and Foote has called attention to their arrangement in directions parallel to the axial planes of the isometric system. No decomposition on exposure to the air has been observed.

*Optical properties.*—Fragments of the mineral, when examined in polarized light, were found to be isotropic. By means of a prism of 79° 35' the following indices of refraction were determined :

$$n_r = 1\cdot5117 \text{ Li.} \quad n_y = 1\cdot5144 \text{ Na.} \quad n_{gr} = 1\cdot5180 \text{ Tl.}$$

*Chemical composition.*—A qualitative examination showed the presence of carbonic acid, chlorine, sodium, magnesium and minute traces of sulphuric acid and water. Potassium was very carefully tested for, but not even a trace of it could be detected.

The results of the analyses are as follows :

|                         | I.    | II.   | Average. | Ratio. |      |
|-------------------------|-------|-------|----------|--------|------|
| CO <sub>2</sub> -----   | 35·21 | 35·02 | 35·12    | ·798   | 2·01 |
| Cl -----                | 14·10 |       | 14·10    | ·397   | 1·00 |
| SO <sub>3</sub> -----   | ·08   | ·08   | ·08      |        |      |
| MgO -----               | 15·96 | 16·20 | 16·08    | ·402   | 1·01 |
| Na <sub>2</sub> O ----- | 36·99 |       | 36·99    | ·597   | 1·50 |
| H <sub>2</sub> O -----  | ·72   |       | ·72      | ·040   |      |
| Insol. -----            | ·25   | ·19   | ·22      |        |      |
|                         |       |       | 103·31   |        |      |
| O equivalent to Cl,     |       |       | 3·16     |        |      |
|                         |       |       | 100·15   |        |      |



The ratio of the  $\text{CO}_2:\text{Cl}:\text{MgO}:\text{Na}_2\text{O}$  is almost exactly 2:1:1:1.5. Two-thirds of the sodium, if taken to form a molecule of  $\text{Na}_2\text{CO}_3$ , would leave just enough to form with the chlorine a molecule of  $\text{NaCl}$ . This would then give as the formula,  $\text{MgCO}_3, \text{Na}_2\text{CO}_3, \text{NaCl}$ .

The percentage composition required by this formula is given below, together with the results of the analysis recalculated to 100 per cent, after deducting the slight amounts of water and insoluble material and converting a sufficient amount of the soda into metallic sodium to unite with the chlorine and form  $\text{NaCl}$ .

|                             | Found.       | Calculated for<br>$\text{MgCO}_3, \text{Na}_2\text{CO}_3, \text{NaCl}$ . |
|-----------------------------|--------------|--|
| $\text{CO}_2$ .....         | 35.43        | 35.41  |
| $\text{MgO}$ .....          | 16.22        | 16.09  |
| $\text{Na}_2\text{O}$ ..... | 24.90        | 24.96  |
| $\text{Cl}$ .....           | 14.23        | 14.28  |
| $\text{Na}$ .....           | 9.22         | 9.26   |
|                             | <hr/> 100.00 | <hr/> 100.00   |

*Pyrognostics.*—Before the blowpipe, the mineral fuses at 1, with frothing, due to escaping carbon dioxide, and yields a white or grayish white mass, which reacts alkaline with moistened turmeric paper. The flame is colored intensely yellow. In the closed tube, the mineral decrepitates violently, sometimes giving off a trace of water, derived probably from impurities held mechanically in the crystals. The crystals are easily soluble in cold dilute hydrochloric and nitric acids with effervescence. Cold water acts slowly on the mineral, but hot water decomposes it very rapidly with separation of magnesium carbonate.

*Name.*—The name, *northupite*, was given to this mineral by Mr. Foote as a compliment to Mr. Northup, whose very careful search has brought to light a number of interesting minerals from this locality.

#### *Pirssonite, a New Mineral.*

As stated in the introduction, a new mineral was first observed by Mr. Northup among some crystals of gaylussite, which it somewhat resembles. It has been found very sparingly in only one boring, "New Well," which also furnished the northupite crystals. With the two exceptions mentioned under northupite, only detached crystals have been observed, and they were probably formed in the same part of the deposit which yielded the northupite. Unfortunately, pirssonite must be classed among the rare minerals; but it is hoped

that, as explorations are carried on, it will be found in other parts of the deposit.

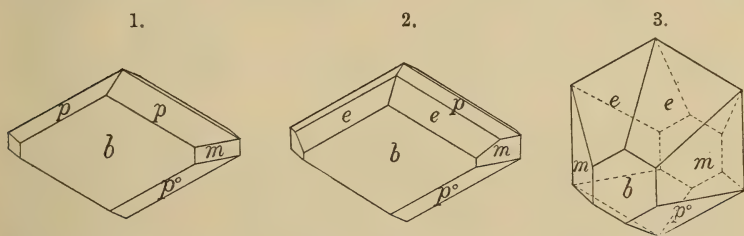
*Crystalline form.*—The mineral crystallizes in the orthorhombic system and is hemimorphic in its development. The hemimorphic axis has been taken as the vertical one, and the forms which have been observed are as follows :

|           |                               |                         |
|-----------|-------------------------------|-------------------------|
| $b$ , 010 | $p$ , 111                     | $e$ , 131               |
| $m$ , 110 | $p^\circ$ , $1\bar{1}\bar{1}$ | $x$ , $3\bar{1}\bar{1}$ |

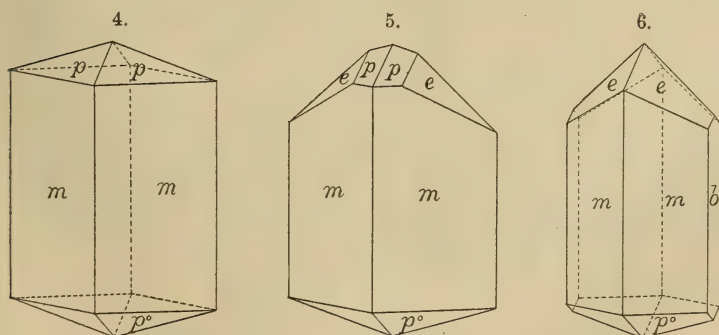
The axial ratio, derived from the measurements marked by an asterisk in the table beyond, is as follows :

$$a : b : c = .56615 : 1 : .3019.$$

Although the forms are not numerous the crystals show a



considerable variety in habit. Figs. 1 and 2, drawn with 010 in front, in order to show the shape better, represent the prevailing types. The pyramid  $e$  is developed at one extremity of the vertical axis only, and varies much in size. Often  $e$  alone terminates the upper end of the crystals, figs. 3 and 6. The pinacoid  $b$  is sometimes wanting as represented by figs. 4 and 5. The pyramid  $x$  was observed on only a single fragmentary crystal and is not represented in the figures. The



crystals vary much in size; the smaller ones, averaging about 5<sup>mm</sup> in greatest diameter, usually have the habit represented by figs. 1 and 2; while the larger ones, sometimes 15<sup>mm</sup> in length, are usually developed like figs. 4 and 5. The larger

prismatic crystals are often only well terminated at that end where the  $e$  faces occur.

The following table includes a list of the measured and calculated angles.

As the reflections were not always very perfect, the extremes of two or more independent measurements are given.

|                 |                                    | Measured.          |                     | Mean.              | Calculated.        |
|-----------------|------------------------------------|--------------------|---------------------|--------------------|--------------------|
| $p \wedge p''$  | $111 \wedge \bar{1}\bar{1}1$       | $62^\circ 57'$     | $-63^\circ 3'$      | $*63^\circ 0'$     |                    |
| $m \wedge m'''$ | $110 \wedge \bar{1}\bar{1}0$       | $59^\circ$         | $-59^\circ 4'30''$  | $*59^\circ 2'$     |                    |
| $p \wedge b$    | $111 \wedge 010$                   | $74^\circ 51'30''$ | $-75^\circ 7'$      | $75^\circ 1'33''$  | $75^\circ 5'$      |
| $p \wedge m$    | $111 \wedge 110$                   | $58^\circ 32'$     | $-58^\circ 47'$     | $58^\circ 38'15''$ | $58^\circ 30'$     |
| $p \wedge p'$   | $111 \wedge \bar{1}11$             | $53^\circ 57'$     | $-54^\circ 5'$      | $53^\circ 59'36''$ | $54^\circ 6'$      |
| $p \wedge p'''$ | $111 \wedge \bar{1}\bar{1}\bar{1}$ | $29^\circ 54'$     | $-29^\circ 59'30''$ | $29^\circ 57'30''$ | $29^\circ 50'$     |
| $b \wedge e$    | $010 \wedge 131$                   | $51^\circ 14'$     | $-51^\circ 43'$     | $51^\circ 26'50''$ | $51^\circ 22'$     |
| $e \wedge e'''$ | $131 \wedge \bar{1}\bar{3}\bar{1}$ | $76^\circ 56'$     | $-77^\circ 12'$     | $77^\circ 4'$      | $77^\circ 16'$     |
| $x \wedge x'''$ | $311 \wedge 3\bar{1}\bar{1}$       | $18^\circ 12'48''$ |                     | $18^\circ 12'48''$ | $18^\circ 10'30''$ |
| $x \wedge m$    | $311 \wedge 110$                   | $36^\circ 44'$     | $-36^\circ 45'$     | $36^\circ 44'30''$ | $36^\circ 15'20''$ |
| $x \wedge m'''$ | $311 \wedge \bar{1}\bar{1}0$       | $49^\circ 26'$     | $-49^\circ 23'$     | $49^\circ 24'30''$ | $49^\circ 24'$     |

*Physical properties.*—The crystals are extremely brittle, breaking with a conchoidal fracture, but with no apparent cleavage. The luster is vitreous. They vary from colorless to white, but are often darkened by impurities. The hardness is between 3 and 3.5. The specific gravity, taken by means of the heavy solution, was found to be 2.352.

The crystals exhibit the phenomena of pyroelectricity in a marked degree. While cooling, after being gently heated, the extremity upon which the acute pyramid  $e$ , 131, is developed, became negatively electrified. This was shown by dusting with a mixture of red oxide of lead and sulphur, as recommended by Kundt.\*

*Optical properties.*—The plane of the optic axes is the base, and the axis  $b$  is the acute bisectrix. The optical orientation is  $a = a$ ,  $b = c$  and  $c = b$ . The double refraction is positive and strong. The dispersion is slight  $\rho < v$ .

For the determination of the indices of refraction the method of total reflection was employed, making use of a crystal upon which a large pinacoid face,  $b$ , 010, was developed. The plate was measured in  $a$  monobromnaphthalene, whose index of refraction for yellow, Na, was found to be 1.6588 at  $23^\circ \text{C}$ . The values obtained were:

$$\begin{aligned}\text{For yellow, Na, } \alpha &= 1.5043 \\ \beta &= 1.5095 \\ \gamma &= 1.5751\end{aligned}$$

By means of the three indices of refraction the value of  $V_{a,y}$  was calculated and found to be  $16^\circ 24'$ .

\* Ann. d. Phys. u. Chem, xx, p. 592, 1883.



With a prism of  $56^{\circ} 41'$ , whose faces were approximately parallel to 110 and  $\bar{1}10$ , the values of  $\beta$  and  $\gamma$  for red, Li; yellow, Na; and green, Tl, were also obtained.

|             | $\beta$ | $\gamma$ |
|-------------|---------|----------|
| Red.....    | 1.5056  | 1.5710   |
| Yellow..... | 1.5084  | 1.5747   |
| Green.....  | 1.5115  | 1.5789   |

The value of  $\beta$  for yellow is probably not as accurate as that obtained by means of total reflection.

The divergence of the optical axes,  $2E$ , was measured on a plate parallel to 010. The values that were obtained are as follows:

|                          | Red, Li.                   | Yellow, Na.     | Green, Tl.      |
|--------------------------|----------------------------|-----------------|-----------------|
| $2E$ at $25^{\circ}C.$ = | $47^{\circ}45'$            | $48^{\circ}14'$ | $48^{\circ}22'$ |
| Hence $2V$ =             | $31^{\circ}11\frac{1}{2}'$ | $31^{\circ}26'$ | $31^{\circ}27'$ |

The value of  $V_{a,y}$  is  $15^{\circ} 43'$  and agrees favorably with the value  $16^{\circ} 24'$  obtained by calculation from the three indices of refraction.

It was observed that the angle  $2E$  varied somewhat, and to determine to what extent this was dependent upon the temperature the following measurements were made:

| Temperature | $20^{\circ}C.$  | $30^{\circ}$    | $40^{\circ}$   | $50^{\circ}$    | $60^{\circ}$    | $70^{\circ}$    | $90^{\circ}$    |
|-------------|-----------------|-----------------|----------------|-----------------|-----------------|-----------------|-----------------|
| $2E_y$ =    | $48^{\circ}16'$ | $48^{\circ}10'$ | $48^{\circ}4'$ | $47^{\circ}55'$ | $47^{\circ}50'$ | $47^{\circ}45'$ | $47^{\circ}38'$ |

*Chemical composition.*—Suitable material for analysis was readily obtained and the results are as follows:

|                   | I     | Found.<br>II | Average. | Ratio. |        |        |
|-------------------|-------|--------------|----------|--------|--------|--------|
| $CO_2$ .....      | 36.23 | 35.91        | 36.07    | .819   | =      | 2.00   |
| $CaO$ .....       | 23.28 | 23.48        | 23.38    | .417   | =      | 1.02   |
| $Na_2O$ .....     | 25.69 | 25.71        | 25.70    | .414   | } .416 | = 1.02 |
| $K_2O$ .....      | .17   | .13          | .15      | .002   |        |        |
| $H_2O$ .....      | 14.74 | 14.73        | 14.73    | .818   | =      | 2.00   |
| $Al_2O_3$ etc. .. |       | .13          | .13      |        |        |        |
| $SiO_2$ .....     | .36   | .22          | .29      |        |        |        |
|                   |       |              | 100.45   |        |        |        |

The ratio for  $CO_2:CaO:Na_2O:H_2O$  is very close to 2:1:1:2, which gives the formula  $CaCO_3.Na_2CO_3.2H_2O$ . The theoretical composition is given below, together with the analysis, after deducting impurities, substituting for  $K_2O$  its equivalent of  $Na_2O$  and recalculating to 100 per cent.

|               | Found. | Calculated for.<br>$CaCO_3.Na_2CO_3.2H_2O$ . |
|---------------|--------|--|
| $CO_2$ .....  | 36.08  | 36.36  |
| $CaO$ .....   | 23.39  | 23.14  |
| $Na_2O$ ..... | 25.80  | 25.62  |
| $H_2O$ .....  | 14.73  | 14.88  |
|               | 100.00 | 100.00                                       |

The chemical composition of this mineral differs from gaylussite,  $\text{CaCO}_3 \cdot \text{Na}_2\text{CO}_3 \cdot 5\text{H}_2\text{O}$ , in having only two instead of five molecules of water of crystallization. Experiments that were made to determine at what temperature the water is driven off from the air-dry powder are as follows :

|                                  | Loss.   |
|----------------------------------|---------|
| Six hours at $100^\circ$ .....   | Nothing |
| Ten hours at $150^\circ$ .....   | 13.85   |
| Three hours at $200^\circ$ ..... | .37     |
| Six hours at $250^\circ$ .....   | .36     |
| Below faint redness .....        | .16     |
| Total .....                      | 14.74   |

As practically all of the water is expelled below  $150^\circ$ , it must be regarded as water of crystallization.

In analysis I the water was weighed directly by the method described by Penfield,\* and in II it was determined by loss on gentle ignition.

*Pyrognostics.*—The mineral decrepitates, when heated before the blowpipe, and fuses about 2—2.5, coloring the flame intensely yellow. It reacts alkaline after heating. In the closed tube it decrepitates and gives off water at a low temperature. It is soluble in cold dilute hydrochloric and nitric acids with effervescence.

*Name.*—The author takes pleasure in naming this mineral *pirssonite*, in honor of his friend and associate, Prof. L. V. Pirsson, of the Sheffield Scientific School.

#### *Gaylussite.*

The only reference that the author has been able to find to gaylussite from this region is in an article by Hanks,† who mentions the mineral as occurring in crystalline masses, but not in distinct crystals. There must have been some mistake in identification, however, for as pointed out by Pirsson,‡ the reactions which are ascribed to the mineral are impossible ones for a compound with the chemical composition of gaylussite.

According to information received from Mr. Northup, the gaylussite occurs abundantly at this locality. It is found in many parts of the deposit and at varying depths. All of the specimens that have been supplied by Mr. Northup have, moreover, been distinct crystals.

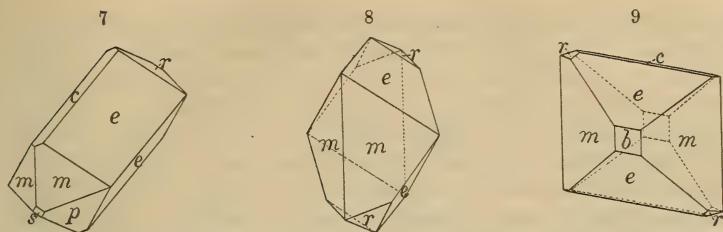
*Crystallization.*—The forms that have been observed are as follows:

|                |                |                |
|----------------|----------------|----------------|
| <i>b</i> , 010 | <i>m</i> , 110 | <i>e</i> , 011 |
| <i>c</i> , 001 | <i>s</i> , 101 | <i>r</i> , 112 |

\* This Journal, *xlvi*, p. 31, 1894.

† Mining and Scientific Press, Mar. 26, 1892.

‡ Zs. Kr., *xxiii*, p. 504, 1894.



Three types of crystals have been observed, represented in figs. 7, 8 and 9. The largest crystals, sometimes 20<sup>mm</sup> in greatest diameter, are developed like fig. 7, but the faces are generally rough. Crystals, with the habit shown in fig. 8, are seldom over 10<sup>mm</sup> in diameter. Only a few crystals of the third type, fig. 9, were observed, and in order to show the development of the faces to better advantage, the figure has been drawn with the pinacoid,  $b\ 010$ , in front. It is only on crystals of the latter type that the pinacoid  $b$ , which is apparently an unusual form on gaylussite, is developed. Although many of the crystals are colorless and transparent, many are cloudy, owing to impurities.

The forms were identified by the following measurements, the calculated angles being derived from the axial ratio established by Phillips: \*

$$a : \bar{b} : c = 1.4897 : 1 : 1.4442; \beta = 78^\circ 26\frac{3}{4}' = 001 \wedge 100.$$

|                |                                    | Measured.                  | Calculated.     |
|----------------|------------------------------------|----------------------------|-----------------|
| $m \wedge m''$ | $110 \wedge 1\bar{1}0$             | $111^\circ 8'$             | $111^\circ 10'$ |
| $m \wedge e$   | $110 \wedge 011$                   | $42^\circ 5\frac{1}{2}'$   | $42^\circ 21'$  |
| $e \wedge e$   | $011 \wedge 0\bar{1}1$             | $109^\circ 34\frac{1}{2}'$ | $109^\circ 30'$ |
| $e \wedge r$   | $011 \wedge \bar{1}12$             | $27^\circ 7'$              | $27^\circ 44'$  |
| $r \wedge r$   | $\bar{1}12 \wedge \bar{1}\bar{1}2$ | $69^\circ 33'$             | $69^\circ 29'$  |
| $r \wedge s$   | $\bar{1}12 \wedge \bar{1}01$       | $39^\circ 49'$             | $40^\circ 21'$  |

The measurements could not be made very accurately, as the small crystals did not give very good reflections of the signal on the goniometer, while the larger ones could only be measured with the contact goniometer.

The specific gravity of some of the purest crystals, obtained by means of the heavy solution, is 1.992. This is somewhat higher than is usually given for this mineral. Phillips,† however, gives practically the same value, 1.990, for a remarkably brilliant crystal upon which he made his crystallographic determinations.

*Optical properties.*—The principal work on the optical properties of this mineral is that by Des Cloizeaux‡ who determined the angle of extinction on the pinacoid  $b\ 010$ , the apparent

\* Philos. Mag. i, p. 263, 1827.

† Ibid., p. 265, 1827.

‡ Ann. d. Mines, V, xiv, p. 400, 1858.



axial angle  $2E$ , and the character of the double refraction and dispersion. The exceptional purity of the material at hand rendered it possible to make more complete determinations. From a plate cut parallel to 010 the extinction  $c \wedge c$  or  $Bx$ , was measured in yellow light and found to be about  $14^\circ 52'$  from the vertical axis, in the acute angle  $\beta$ . For red the angle was about one degree greater.

These values cannot be regarded as very exact, as the specimens, which were best adapted for optical work, did not show very perfect crystal outline. They differ, however, only slightly from the values given by Des Cloizeaux,\*  $c \wedge c$  or  $Bx$ , for red= $14^\circ 48'$  and for blue= $13^\circ 8'$ .

The acute bisectrix is normal to 010 and the following values of the apparent axial angle were obtained :

| Red, Li.                            | Yellow, Na.              | Green, Tl.                |
|-------------------------------------|--------------------------|---------------------------|
| $2E$ at $26^\circ C = 51^\circ 26'$ | $52^\circ 7\frac{3}{4}'$ | $52^\circ 47\frac{3}{4}'$ |

These values agree closely with those obtained by Arzruni,† which are as follows :

| Red, Li.            | Yellow, Na.    | Green, Tl.     |
|---------------------|----------------|----------------|
| $2E = 51^\circ 25'$ | $52^\circ 19'$ | $52^\circ 58'$ |

Des Cloizeaux gives :  $2E = 51^\circ 38'$  for red and  $52^\circ 53'$  for blue.

Crossed dispersion could be distinctly observed and the character was  $\rho < v$ . The double refraction is negative and strong. By means of total reflection the following values of the indices of refraction, for yellow light, Na, were obtained.

$$\alpha = 1.4435 \text{ Na.} \quad \beta = 1.5156 \text{ Na.} \quad \gamma = 1.5233 \text{ Na.}$$

From the foregoing values  $V_y$  was calculated and found to be  $17^\circ 32'$ , while  $16^\circ 53'$  was obtained from the values of  $2E_y$  and  $\beta$ .

Des Cloizeaux has shown that the axial angle varies considerably with the temperature, and a series of experiments has been made to illustrate this, the results of which are shown in the following table :

| Temperature. | Apparent Angle.<br>$2E_y$ . Na. | Température. | Apparent Angle.<br>$2E_y$ . Na. |
|--------------|---------------------------------|--------------|---------------------------------|
| $22^\circ C$ | $52^\circ 6'$                   | $60^\circ C$ | $54^\circ 7'$                   |
| $30^\circ$   | $52^\circ 32'$                  | $70^\circ$   | $54^\circ 43'$                  |
| $40^\circ$   | $52^\circ 54'$                  | $80^\circ$   | $55^\circ 13'$                  |
| $50^\circ$   | $53^\circ 26'$                  | $90^\circ$   | $55^\circ 48'$                  |

The maximum variation from  $22^\circ$  to  $90^\circ C$ . is therefore  $3^\circ 42'$ .

\* Ann. d. Mines, V, xiv, p. 400, 1858.

† Zs. Kr., vi, p. 24, 1882.

For red, Des Cloizeaux measured  $51^{\circ} 50'$  at  $21.5^{\circ} \text{C.}$  and  $53^{\circ} 32'$  at  $71.5^{\circ}$ , a variation of  $1^{\circ} 42'$ .

### *Hanksite.*

This mineral was first identified in 1885 by Mr. W. E. Hidden,\* who observed some crystals with hexagonal habit marked thenardite, in the mineral exhibit from California, at the World's Industrial and Cotton Centennial Exposition, held in New Orleans. Upon examination these crystals proved to be a new mineral, to which the name, *hanksite*, was given in honor of Mr. H. G. Hanks, formerly State Mineralogist of California.

The mineral occurs at Borax Lake in many places. According to information received from Mr. Northup, short crystals with prominent basal planes are found near the surface, either attached to the under side of the crust, already referred to on page 124 of this article, or in the mud directly beneath this. The habit of these crystals is illustrated by figures in the articles by Hidden and Hanks.† Beneath the crust, for a distance of about 50 feet, hanksite crystals are rare, but at this depth a stratum of mud was encountered, containing a few crystals with a habit somewhat resembling quartz, shown in fig. 10. The crystals were etched to such an extent that they could not be measured with the reflection goniometer, but by means of the contact goniometer the forms were identified as the prism  $m$ ,  $10\bar{1}0$ , and the unit pyramid  $o$ ,  $10\bar{1}1$ .

*Optical properties.*—As the indices of refraction of hanksite had not been determined, a basal section was prepared from a tabular crystal, and by means of total reflection the following values were obtained:

For yellow, Na,  $\omega = 1.4807$ .  $\epsilon = 1.4614$ .

The section showed a normal uniaxial interference figure and a strong negative double refraction.

*Chemical composition.*—Our knowledge concerning the chemical composition of hanksite is confined to two analyses. One by Mackintosh, quoted by Hidden,‡ from which the formula,  $4\text{Na}_2\text{SO}_4 + \text{Na}_2\text{CO}_3 + \frac{1}{2}\text{NaCl}$  was derived. Sodium chloride, however, was regarded as non-essential and  $4\text{Na}_2\text{SO}_4 + \text{Na}_2\text{CO}_3$  was suggested as the probable formula. It should be pointed out, however, that a mistake in the calculation of the analysis was made, for while the ratio of  $\text{Na}_2\text{SO}_4 : \text{Na}_2\text{CO}_3 : \text{NaCl}$  is given as  $3.95 : 1 : .46$  or  $4 : 1 : \frac{1}{2}$ , it should have been

\* This Journal, xxx, p. 33, 1885.

† Ibid., xxxvii, p. 66, 1889.

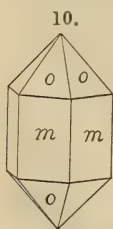
‡ Ibid., xxx, p. 134, 1885.

4.6 : 1 : .53. The analysis is also incomplete since the bases are calculated wholly as soda.

An analysis has also been made by Penfield \* on material from a large crystal presented to the Brush collection by the late Prof. J. S. Newberry. It was quite impure, apparently owing to included clay, the analysis giving 4.41 per cent. of insoluble material and 1.32 per cent. loss on ignition. In addition to sodium, 2.33 per cent. of potassium was determined, which is just sufficient to unite with the 2.13 per cent. of chlorine to form potassium chloride. An examination of a section of this crystal by Prof. E. S. Dana † showed numerous rectangular inclusions, supposed to be either sodium or potassium chloride. The material was regarded as too impure to warrant the establishment of a complicated formula, and the results of the analysis, after deducting the insoluble material, loss on ignition and KCl, approximated to the formula  $4\text{Na}_2\text{SO}_4 + \text{Na}_2\text{CO}_3$ , suggested by Mackintosh.

In making the optical examination of the hanksite it was observed by the author that although the sections, when examined with the microscope, showed trifling impurities, nothing of an isometric character could be detected. Moreover, on testing numerous crystals for chlorine, it was found to be invariably present, and since the results by Penfield and Mackintosh have shown that the mineral contains an amount of chlorine corresponding to over 4 per cent. of sodium or potassium chloride, it is not possible that either of these latter compounds could be present to such an extent, as an impurity, without being detected with the microscope. It was suggested, therefore, by Prof. Penfield, that new analyses, made on the exceptionally pure material now at hand, might indicate that chlorine is an essential constituent of the mineral.

Some flat tabular crystals were, therefore, selected, and in order to free them as far as possible from any impurities they might contain, they were crushed and sifted to a uniform grain and separated by means of methylene iodide. Most of the material varied in specific gravity between the narrow limits 2.567 and 2.553, and this was used for the analysis.



The prismatic crystals, fig. 10, derived from the stratum of mud fifty feet below the surface, appeared even purer than the above, and, fortunately, enough of these had been supplied by Mr. Northup for an analysis. The specific gravity was found to be 2.545.

The results of the analyses of the two samples are as follows :

\* This Journal, xxx, p. 137, 1885.

† Loc. cit.



|                         | Tabular Crystals. |       | Average Ratio. |            | Prismatic Crystals. |            |
|-------------------------|-------------------|-------|----------------|------------|---------------------|------------|
|                         | I.                | II.   |                |            | III.                | Ratio.     |
| SO <sub>3</sub> .....   | 45·89             | 45·98 | 45·93          | ·574= 9·   | 45·78               | ·572= 9·   |
| CO <sub>2</sub> .....   |                   | 5·65  | 5·65           | ·128= 2·01 | 5·63                | ·128= 2·01 |
| Na <sub>2</sub> O ..... | 43·27             | 43·43 | 43·35          | ·699=10·95 | 43·61               | ·703=11·07 |
| Cl .....                |                   | 2·21  | 2·21           | ·062= ·97  | 2·28                | ·064= 1·01 |
| K .....                 | 2·40              | 2·55  | 2·48           | ·063= ·98  | 2·39                | ·061= ·96  |
| Insol. ....             | ·22               | ·16   | ·19            |            | ·12                 |            |

The analyses are almost identical, indicating that chlorine and potassium are not accidental constituents. The ratios of SO<sub>3</sub>:CO<sub>2</sub>:Na<sub>2</sub>O:Cl:K are very close to 9:2:11:1:1 corresponding to the formula 9 Na<sub>2</sub>SO<sub>4</sub> + 2 Na<sub>2</sub>CO<sub>3</sub> + KCl.

Of the previous analyses, that of Mackintosh yields the ratio of SO<sub>3</sub>:CO<sub>2</sub>:Cl = 9:1·93:1·04, fully supporting the above formula, but no further comparison can be made, as the bases were calculated wholly as soda. The analysis of Penfield gives the ratio SO<sub>3</sub>:CO<sub>2</sub>:Na<sub>2</sub>O:Cl:K = 9:2·03:10·89:·99:·99, which is fully in accordance with the above formula.

Further, in order to show the close agreement between the analytical results and the theoretical composition, the analyses with the exception of that of Mackintosh are given below, after deducting impurities and recalculating to 100 per cent.

|                         | Tabular Crystals. | Prismatic Crystals. | Penfield's. | Theory. |
|-------------------------|-------------------|---------------------|-------------|---------|
| SO <sub>3</sub> .....   | 46·11             | 45·92               | 46·21       | 46·02   |
| CO <sub>2</sub> .....   | 5·66              | 5·65                | 5·74        | 5·62    |
| Na <sub>2</sub> O ..... | 43·53             | 43·74               | 43·32       | 43·59   |
| Cl .....                | 2·215             | 2·29                | 2·26        | 2·26    |
| K .....                 | 2·485             | 2·40                | 2·47        | 2·49    |
|                         | 100·00            | 100·00              | 100·00      | 100·00  |

With the close agreement of these three complete analyses, together with the partial one of Mackintosh, made on entirely different samples, on crystals collected at different times and from different parts of the deposit, there can be no doubt that both potassium and chlorine are essential constituents of the compound and the somewhat complicated formula, 9Na<sub>2</sub>SO<sub>4</sub>. 2Na<sub>2</sub>CO<sub>3</sub>. KCl is the correct one. It is scarcely possible that potassium and sodium are isomorphous in this mineral, for potassium seems always to be present in quantity just sufficient to form KCl with the chlorine. The compound furnishes a very interesting example of the exceptionally rare occurrence of three acid radicals in a mineral.

In conclusion, the author wishes to express his indebtedness to Prof. S. L. Penfield for his valuable advice and assistance, and also for his very kind interest in the work, throughout the entire investigation.

Mineralogical Petrographical Laboratory,  
Sheffield Scientific School, May, 1896.

ART. XVI.—*The Bearpaw Mountains of Montana. Second Paper*;\* by WALTER HARVEY WEED and LOUIS V. PIRSSON.

[Continued from page 362 of vol. i.]

IN our first paper on this interesting mountain group in the April and May numbers of the preceding volume of this journal, we described the extrusive igneous rocks and those forming the stock at the head of Beaver Creek. In the present communication we propose to describe several other intrusive masses, a leucite lava from Bearpaw Peak, and finish with an account of some of the dikes occurring so abundantly throughout the region.

*Augite Syenite of Wind Butte.*

There are several other igneous centers in the Bearpaw Mountains besides that of Beaver Creek, for the altered sedimentary rocks of the contact zones of such intrusive masses were noted at several localities, though but one other of these stocks was visited. This intrusion occurs at the head of Wind Creek, just north of Wind Butte, the highest point of the northern part of the mountains. The presence of an igneous center in this vicinity is clearly indicated by the large number of radial dikes observed cutting the ridges about the intrusive, as well as by the indurated and altered character of the sedimentaries which they cut. The sedimentary beds about this core are tilted at considerable angles, flattening in dip as the distance from the stock increases, so that the intrusion is seen to have tilted the sedimentary strata as at the Beaver Creek core.

In a basin at the extreme head of Wind Creek the massive granular rock is seen, forming a talus slope above the springs in which the stream heads. The rock is an *augite syenite*. It has a clear gray color, is of rather fine, even grain and highly feldspathic; very little of any dark-colored component is visible. With a lens it is seen to be evenly though quite sparsely sprinkled with very small black augites. An occasional cleavage of feldspar appears by reflected light to be much larger than the average size of grain, which is about 1<sup>mm</sup>. It resembles the quartz syenite of the Beaver Creek core in structure, granularity, and appearance.

Under the microscope the composition is seen to be very simple, *augite*-*augite* and *microperthite* being the chief components, with a little accessory *iron ore*, *apatite*, *biotite*, *titanite*, *hornblende*, and *sodalite*.

\* Published by authority of the Director of the United States Geological Survey. Field observations and collections by W. H. W., petrography by L. V. P.

The *ægirite-augite* is in stout to slender prisms not of good idiomorphic shapes; it is often diopside-like in the center and increases in *ægirite* to the edge; at other times small anhedralons are seen of quite pure *ægirite*, as shown by the extinction angle.

The *feldspar* has a tendency to a broad lath-shaped form, with the interspaces filled by smaller rounded grains of the same mineral. It is sometimes single, sometimes twinned according to the carlsbad law; more rarely baveno twins are seen. Examined with very low powers, it appears nearly homogeneous; with very high powers, it is seen to be a mixture of albite and orthoclase in very fine little specks that mottle each other and fade away indefinitely, giving the surface a flamed, mottled appearance. No albite or pericline twinning is seen in it. It is filled with minute microlites of pyroxene. It presents the common characters of the soda-orthoclase seen in rocks of this class and needs no further mention.

The *sodalite* is rather rare and occurs only as minute masses filling small angular interspaces. Its presence was proved by a chemical test for chlorine.

The presence of an occasional apatite grain, shred of brown pleochroic biotite, and of a little greenish brown hornblende was also noted, as well as small characteristic crystals of titanite and, very rarely indeed, a little iron ore.

The structure is the characteristic one of abyssal rocks, composed of formless interlocking grains; it is hypidiomorphic. The rock contains numerous angular inclusions of basic rock, some finer grained than the syenite and others as crystalline. They probably represent fragments of a partly consolidated basic rock that is one of the products of the differentiation of the intrusive mass.

The presence of this alkali syenite in connection with the other types described in the Bearpaw Mountains is very interesting and indicates that a study of this core or stock may be expected to yield very interesting petrologic results.

#### *Intrusive Trachyte, near Lloyd.*

The postoffice of Lloyd is situated in the northeastern part of the Bearpaw Mountains, on the headwaters of Snake Creek. The mail route from Chinook passes Bean Butte, an isolated hill of basaltic breccias, and crosses a low gap in the rough chain of basaltic hills lying between Bean and Snake creeks, and through the meadows of a hill-environed basin cut in soft Cretaceous shales. A steep hillside immediately east of the postoffice is seen to be capped by a massive cliff, whose talus slopes extend down to the road. The cliff is formed of a mass of igneous rock intruded in tilted argillaceous shales.



The rock is a light-colored *trachyte* carrying included fragments of minette, the weathered surface being pitted with the rusty cavities left by the decomposition and weathering out of these micaceous inclusions, giving the rock a porous appearance. It breaks into rather small debris, the pieces averaging 5 to 6 inches across. The exposure is but a few hundred yards in diameter and the rock is surrounded by a narrow contact ring of indurated, altered sedimentary rocks. The intrusive mass is covered by these hornstones, the ridge above the postoffice showing occasional detached parts of the cover resting upon the massive igneous rock. It is evident that the intrusive is laccolithic in character, or at least has uplifted and tilted the sediments into which it has been intruded. A hundred feet up the slope the igneous rock holds included fragments of baked shale, much twisted and warped, and the porphyry itself shows slickenside surfaces indicating some movement after consolidation.

In the hand specimen the rock has a brownish gray color and a rough trachytic feel. It appears plainly holocrystalline to the eye, showing a fine granular groundmass that is sprinkled with numerous phenocrysts. The fine groundmass is seen to be chiefly feldspathic, but it is thickly peppered throughout with very small leaves of biotite which grade to microscopic dimensions and which give the rock its brownish tone. No dark mineral appears as a prominent phenocryst. Very thickly scattered through this groundmass are the phenocrysts of feldspar, which is clear, glassy, and of the sanidine habit; it is usually developed columnar on the  $a$  axis though sometimes short, thick tabular parallel to the  $b(010)$  face and reaches dimensions of  $1^{\text{cm}}$  in length. It is quite idiomorphic and bounded by the  $m(110)$ ,  $b(010)$ , and  $c(001)$  faces.

Besides these phenocrysts the rock is quite thickly dotted with inclusions, angular or subangular in shape, of what appear to be a basic rock, and also of shale fragments brought up from below. They are rather small in size, not often reaching  $1^{\text{cm}}$  in diameter, and they appear to have been subjected to intense endogenic metamorphism. Some are dense and black, while others are rich in biotite and appear like inclusions of minette. Their former nature can only be surmised, as they are altered and usually converted into masses of limonite, etc., though the containing rock is quite fresh. Some of them present sections which recall resorbed olivines or hornblendes.

In thin section the microscope discloses the presence of the following minerals: *Apatite*, *titanite*, *iron ore*, *hornblende*, *augite*, *biotite*, *alkali feldspar*, *quartz*, and some *calcite* and decomposition products.

The large *feldspar* phenocrysts are of orthoclase. This is

clearly shown by a section parallel to  $b(010)$ , which shows the outline of  $a(100)$  and  $c(001)$ . The angle  $c(001)$  on  $a(100)$  was measured as  $65^\circ$ , while Or, ang.  $\beta = 63^\circ 56'$ . The section shows a positive obtuse bisectrix centered in the field, and the extinction is  $5^\circ$  from the trace of the cleavage  $c(001)$  in a positive sense. Cleavage fragments show that the basal cleavage  $c(001)$  is much better than that of  $b(010)$ ; such fragments placed on this face have an extinction so nearly as can be told exactly parallel to the edge of  $c(001)$  on  $b(010)$ . These are the exact optical characters of orthoclase; we do not know, however, how much of soda in the shape of the albite molecule the phenocrysts may contain; toward the periphery they are zonally built as best seen in the clinopinacoid section, and as this occurs the angle of extinction rises gradually from  $5^\circ$  to  $10^\circ$  in a positive sense, the latter angle obtaining at the outer border, the birefracton rising at the same time. This appears to point clearly to an increase in the albite molecule as the periphery is reached. In other sections flame-shaped tongues and patches of this feldspar substance of higher birefracton penetrate and spot the orthoclase. The only twinning observed was that according to the carlsbad law, and the phenocrysts are often bunched and grown together in groups.

The feldspar composing the groundmass is in allotriomorphic granules, which average  $0.25\text{mm}$  in diameter. It appears quite similar in character to the large phenocrysts, but is much more turbid from kaolinization so that it does not lend itself well to optical investigation; it is untwinned and may safely be assumed as soda orthoclase or anorthoclase. A few sections were observed which showed in very minute laminae the albite twinning; they were too few and the twinning too fine to afford material for investigation. They may be of anorthoclase.

Between the feldspars are occasional minute anhedral of quartz, evidently primary and the last product of crystallization.

Of the dark minerals the *hornblende*, in small, rare patches, is deep green and pleochroic into yellow. It has a small angle of extinction and its birefracton is very low; it appears arfvedsonite-like in its character. It nearly always appears as if partly resorbed and is surrounded by borders of a very pale reddish-brown variety with a similar orientation, and which is more or less fibrous in character.

The *augite* is present in idiomorphic prismatic crystals, which vary from long slender columns to short thick ones. The largest seen are about  $1\text{mm}$  long. The color is quite variable; some are almost colorless, while others are a clear light-green and faintly pleochroic; the two colors are often found

in the same crystal, the green surrounding a colorless core; at other times the colors are irregularly mingled. The largest crystals of pyroxene appear to be partly resorbed; these are rather rare, while a smaller generation is abundant in the groundmass. Small prisms of the pyroxene are common inclusions in the large feldspar phenocrysts.

The *biotite* appears also in two generations; the large crystals which attain 1<sup>mm</sup> in diameter are rare; they are irregular and embayed and appear as if partly resorbed. It is strongly pleochroic between a deep chocolate-brown and colorless. A slight opening of the axial cross in a very thin basal section permits us to determine it as *meroxene*. In the second generation it is freely scattered through the groundmass in small shreds and patches. The iron ore, titanite, and apatite which occasionally occur offer no peculiarities worthy of notice.

The structure of the groundmass is allotriomorphic, granular, and from what has been said it is clear that the rock might be classed as a syenite porphyry which has in the hand specimen a trachytic appearance and habit. Since, as has been previously mentioned, it is certain that the Bearpaw rocks are of Tertiary age, it follows that by those who still recognize the age distinction in petrography, it would indeed be classed as a trachyte. We have, however, in these papers used the terms in a purely structural sense, without reference to age.

#### *Nephelite Basalt Intrusion, near Lloyd.*

A couple of miles south of Lloyd on the headwaters of Snake Creek, a dark-colored rock is exposed by the roadside and is seen outcropping on the slopes to the east. The exact geological relations were not determined, but it is intrusive in slightly tilted, soft Cretaceous shales, which are somewhat metamorphosed near the contact. The rock occurs in quite large blocks, breaking with conchoidal fracture. It was recognized in the field as being of unusual character, and this is confirmed by petrographic study.

On a fresh fracture it is a very dark stone-gray color and is quite thickly dotted with small, well crystallized prisms of black augite, which vary from 1 to 2<sup>mm</sup> in length and are of stout, thick habit. Much more rarely yellow grains of olivine are seen of about the same size. The groundmass has a somewhat greasy appearance, whose dark-gray color gives the rock its prevailing tint. It is very dense and compact, and under the lens it can be seen to be of crystalline character. On weathered surfaces the rock has a rusty brown color, dotted and pitted by the altered augites.



In thin sections the following minerals are seen: *apatite*, *iron ore*, *augite*, *olivine*, *biotite*, *nephelite*, *alkali felspar*, and *sodalite*.

The *augite* phenocrysts are perfectly idiomorphic and bounded by the usual planes  $m(110)$ ,  $a(100)$ , and  $s(11\bar{1})$ ; the mineral is a very pale olive brown, almost colorless in the section, and has all the characteristics of basaltic augite. It is sometimes filled with small inclusions of glass having irregular shapes. It shows no trace of alteration.

The *olivine* is remarkably fresh and unaltered, and is perfectly colorless and limpid; it is not so idiomorphic as the pyroxene and is much less common. It contains inclusions of iron ore, glass, and occasional grains of pyroxene; smaller crystals are free from these inclusions.

The *biotite* is far less common than either of the minerals noted and in bulk amount does not compare with them. It does not occur in well formed tablets as is usual with this mineral, but in formless, embayed, ragged patches and very commonly a number of these lying near together have a similar crystallographic orientation and extinguish simultaneously, thus resembling a poikilitic structure. It quite vividly recalls the embayed, skeleton brown hornblendes and biotites in the nephelite tephrite from Langehansküppel by Poppenhausen in the Rhöngelbirge (buchonite of Sandberger), and may like them be only the remains of formerly larger resorbed crystals; it does not, however, show any opacite borders. It has the rich red-brown color that so frequently distinguishes biotite in rocks of this class and in the theralites. It is apparently uniaxial. Where it occurs it is noticeable that the minute grains of iron ore which dot and pepper the groundmass are for considerable areas around it almost entirely lacking—the iron evidently being consumed in its production. It contains inclusions of apatite, iron ore, and grains of pyroxene, the last two more rarely.

*Apatite* occurs in very small prisms and in moderate amount; is very often in the mica.

The *groundmass*, in which these minerals lie, is clear and colorless, dotted with small anhedral grains of pyroxene and minute octahedra of iron ore—a little of the iron ore is present in larger grains—the pyroxenes and iron ore being a second generation. While the amount of pyroxene is considerable, it is by no means so preponderant an ingredient as is commonly the case in the nephelite basalts of Germany, where, especially in the finer grained forms, the anhedral grains of augite are so thickly crowded together in the groundmass. In ordinary light there appears in this rock a large proportion of the colorless groundmass, and seen in this way

the rock recalls strikingly certain monchiquites described by Kemp\* in the Lake Champlain district. It differs of course from these in the character of the base. In polarized light this colorless base breaks up into patchy, irregular, allotriomorphic areas, with gray polarization colors. Some sections remain dark during a revolution and in convergent light these furnish the faint, negative, uniaxial interference figure of nephelite. Other sections show the exit of a bisectrix and that a biaxial mineral, a feldspar, is also present; these present at times the appearance of twinning according to the carlsbad law, no albite twinning being seen. Careful study of the section shows that the feldspar is not a plagioclase but an alkali feldspar, which in all probability is anorthoclase from its association with nephelite, but the optical means at present available are not decisive in separating this feldspar from sanidine.

Occasionally, with high powers, a rounded area surrounded by minute grains of pyroxene and iron ore which define it may be found; they are of a pale brownish color, and are an isotropic mineral which commonly appears faintly birefractive from partial zeolitization. It is referred to sodalite. The rock powder treated with dilute nitric acid gelatinizes abundantly, confirming the presence of the nephelite; the solution gives a strong reaction for chlorine, confirming the presence of the sodalite; there is no reaction for sulphates, thus excluding haunyn and nosean.†

From the description given it is evident that this rock is a *nephelite basalt*. It does not, it is true, present the black appearance and dense texture so characteristic of the nephelite basalts common in central Europe, but appears like a compact, fine-grained intrusive; on the other hand, it does not show the coarse-grained character indicative of the truly abyssal rocks. It is evidently closely allied to the lamprophyre group and shows certain analogies to the absarokite of Iddings.‡ Since, however, in mineral composition and in appearance, both in the hand specimen and in thin section, it is most closely

\* Bull. 107, U. S. Geol. Surv., 1893.

† In this connection it may be worthy of notice that rocks containing an appreciable amount of nephelite may be powdered and safely tested for gelatinization in the presence of olivine, if very dilute nitric acid is used. By experiment it has been found that pure, finely-powdered nephelite dissolves easily and rapidly in a solution so weak as one part of pure concentrated nitric acid in forty parts of water, yielding gelatinous silica upon evaporation. Thus in the present case a bulk of finely powdered olivine equal in amount to the rock taken, was treated with very dilute acid under the same conditions. Upon boiling a few moments and then filtering, the filtrate upon evaporation yielded only a very small amount of gelatinous silica, while the filtrate from the rock powder gelatinized abundantly. Under these conditions the very small amount of olivine in the rock could have yielded only an inappreciable amount of gelatinous silica.

‡ Jour. of Geol., vol. iii, No. 8, p. 935, 1895.

related to the nephelite basalts, it has been referred to that group.

So far as our knowledge goes, these rocks have been described from only two occurrences in this country. The first of these is at Pilot Knob in Texas, described by Hill and Kemp,\* and the second is in the Cripple Creek district in Colorado, where their presence in dikes has been mentioned by Cross.† Allied rocks have been described by Zirkel‡ from the Kawsoh and Elkhead mountains, but since they contain plagioclase it would appear that they should rather be referred to the tephrites.

#### *Leucitite of Bearpaw Peak.*

The highest summit of the mountains is known as Bearpaw Peak. It is situated in the western part of the region, and its dark conical point, rising far above the neighboring summits, is the most prominent feature of the mountains. This prominence is due to its greater height (7040 feet) and to the fact that it stands apart from the adjacent summits, from which it is separated by meadows and a lower hilly region in which the numerous streams radiating from the peak find their sources. From the top there is an excellent outlook over the entire mountain area. The smooth grassy slopes and lack of rocky exposures seen everywhere convince one that rapid geological mapping is not possible; each point must be actually visited to ascertain its nature. No actual dikes are seen, but the grassy lines seaming the butte immediately west of the peak represent minette-like dikes cutting metamorphosed sedimentary rocks.

The mountain is formed of extrusive rocks, which are all basaltic and consist of varying forms of scoria, breccia, and bedded tuffs with occasional intercalated lava flows. Good exposures are not rare, though the summit and sides of the mountain are covered by a mantle of debris extending far down its slopes.

The rocks are leucite basalts, varying as greatly in color as in physical nature and presenting different phases of this type of rocks. The prevailing type is similar to that described in the first part of our former paper.

About midway upon the northern flanks of the mountain a dark-gray, almost black rock occurs. A prospect is located near by, though there was no sign of ore seen. The rock

\* *Am. Geologist*, Nov. 1890, p. 286.

† Pike's Peak Folio, *Geol. Atlas*, No. 7, U. S. Geol. Survey, 1894. Also *Geol. Cripple Creek Dist.*, 16th Ann. Rep. U. S. Geol. Surv. 1895, p. 49.

‡ *Surv. 40th Parallel*, vol. vi, *Micro. Petrog.*, pp. 255, 256, 1876.



appears to be part of a lava flow intercalated in the breccias, and proves to be a *leucitite* or olivine free leucite-basalt. As but few American occurrences of leucite rocks are known, it is of unusual interest.

The rock is very dark gray on a fresh surface, quite dense, with conchoidal fracture, and has a pronounced basaltic habit. It does not contain either pores or the open structure due to vapor. In the dark, compact groundmass occasional phenocrysts are seen. Very rarely *biotite* occurs in rather thick, well formed bright, bronzy-brown tablets which vary from 5<sup>mm</sup> to 10<sup>mm</sup> in diameter. Much more common are prisms of a green *diopside*, mostly very small, and round white sections of *leucite* which are from 1 to 2<sup>mm</sup> across.

In the thin sections the minerals are found to be phenocrysts of *biotite*, *augite*, and *leucite* in a groundmass of thickly crowded leucites with a very little glass base. One or two large ore grains were seen. No olivine is present and the rock is therefore a leucitite.

The *biotite* is so rare that only one or two flakes have been seen, and one large phenocryst that should have appeared has, unfortunately, been almost destroyed in grinding. Sufficient remains, however, to show that it is strongly pleochroic between a peculiar dark reddish yellow and nearly colorless. Cleavage plates furnishing basal sections are found not to be entirely dark during revolution, but to indicate a considerable obliquity of the axes of elasticity. It shows in convergent light a pronounced biaxial character and is a merxene: with the movable thread micrometer ocular there was determined

$$2E = 38^{\circ},$$

which was found to be the same on two plates. This is a large angle for a *biotite*, but Tschermak \* gives  $2E = 56^{\circ}$  for one which is also from a leucitic rock, the tuff of the Monti Albani in Italy.

These *biotites* are partly resorbed and bordered by masses of opacite grains; everything, indeed, points to an earlier intratelluric period of formation for the mineral.

The *augite* appears in section of a very pale olive brown; it is idiomorphic, has a good cleavage, is fresh, unaltered, rarely contains glass inclusions, and there is not very much of it. It has a wide extinction angle and appears present in only one generation.

The *leucite* phenocrysts are quite well crystallized, very clear, limpid and fresh; they are free from inclusions, as is

\* Ber. Ak. Wien., lxxviii (1), p. 21, 1887.

usually the case in the larger leucites of leucitic rocks, and they show the cross bands of twinning, best seen with a sensible violet tone. Only the faintest traces of the beginnings of zeolitization can be seen along occasional cracks. They are of perfectly normal character as seen in rocks of this class, and offer nothing of especial interest.

The case is, however, quite otherwise with the little leucites that compose the *groundmass*. They vary in size from .05 to .10<sup>mm</sup> and are thickly crowded together. They exhibit different stages of growth that the mineral has passed through, and by study and comparison these may be easily traced out, and arranged as shown in the adjoining fig. 1. In *a* we have the

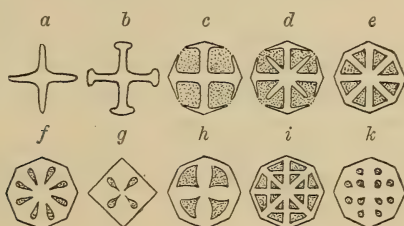


FIG. 1. Forms of leucite growth in leucite of Bearpaw Peak.

first stage, a simple growth along the cubic axes. In *b* these are thickened by club-shaped ends which by further growth begin to define the leucitohedron as in *c*; here for the first time the included glass base is shown by the dotted areas. In the next stage, as seen in *d*, growths along the dodecahedral axes start from the center, finally advancing and completing the outline, when a wheel-shaped figure is produced as seen in *e*. The final stage consists in the production of material along the octahedral axes and the completion of the outer surface of the leucitohedron, when the process of growth ceases and the crystal then has a club-shaped inclusion of glass projecting from the center of each icositetrahedral face inward toward the center. A median section then gives the appearance shown in *f*.\* By far the greater number of sections appear like *f*, though *c*, *d*, and *e* are very common, with *a* and *b* less so. The sections often exhibit the figures given with almost ideal symmetry, and more interesting sections of leucite for purposes of study have rarely, if ever, been seen.

It is evident if a crystal like *f* were cut through near the

\* Somewhat similar skeleton leucites from Vesuvius have been described by Sinigaglia, *Jahrb. Min. Beil.*, vii, 1891, p. 417.

periphery it would furnish a section like *g*; these are very rare; more often it is represented by *h*, which shows it in a ruder, less perfect stage. The section *i* shows an anomalous form observed several times and in *k* is seen a cut half way between the center and edge of a crystal with slender glass rods as in *f*. The location of each trapezohedral face is marked by the cross section of its inclusion. These also occur in various degrees of perfection.

Studied with very high powers, it is seen that the inclusions in these leucites have not remained a homogeneous glass, but have partly crystallized and contain globulitic material and granules of iron ore.

The base which surrounds the leucites and cements them together appears, with low powers, a dark brownish glass; with high powers, it is a confused mixture of ore grains, globulitic material, and minute indeterminable microlites that act faintly on polarized light, all cemented together with glass. Probably the microlites are in part a pyroxene.

The structure and proportion of the minerals to each other is shown in fig. 2, which presents the rock in a somewhat diagrammatic way.

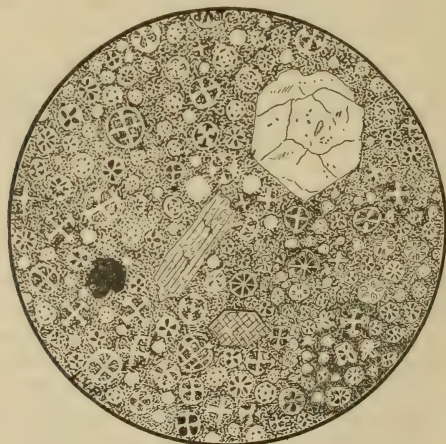


FIG. 2.—Leucitite of Bearpaw Peak. Augite, iron ore, leucite. Actual field 1 mm.  $\times$  50.

The analysis of this interesting lava is given in No. 1 of the following table. It was made for us by Dr. H. N. Stokes of the chemical laboratory of the U. S. Geological Survey.



|                                      | I.          | II.          | III.         | IV.         | V.           | Ia.  |
|--------------------------------------|-------------|--------------|--------------|-------------|--------------|------|
| SiO <sub>2</sub> .....               | 46.51       | 48.12        | 47.53        | 54.42       | 47.28        | .775 |
| Al <sub>2</sub> O <sub>3</sub> ..... | 11.86       | 17.16        | 19.49        | 13.37       | 11.56        | .115 |
| Fe <sub>2</sub> O <sub>3</sub> ..... | 7.59        | 5.69         | 2.04         | .61         | 3.52         | .047 |
| FeO .....                            | 4.39        | 5.13         | 5.24         | 3.52        | 5.71         | .061 |
| MgO .....                            | 4.73        | 3.99         | 4.10         | 6.37        | 13.17        | .118 |
| CaO .....                            | 7.41        | 9.84         | 10.09        | 4.38        | 9.20         | .132 |
| Na <sub>2</sub> O .....              | 2.39        | 2.77         | 2.67         | 1.60        | 2.73         | .038 |
| K <sub>2</sub> O .....               | 8.71        | 7.24         | 7.12         | 10.73       | 2.17         | .092 |
| H <sub>2</sub> O—110° .....          | 1.10        | ----         | ----         | ----        | ----         | ---- |
| H <sub>2</sub> O+110° .....          | 2.45        | .08          | .48          | 2.76        | 2.96         | ---- |
| TiO <sub>2</sub> .....               | .83         | .22          | .25          | ?           | .88          | ---- |
| Fl .....                             | trace       | none         | none         | ----        | ----         | ---- |
| Cl .....                             | .04         | not det.     | not det.     | ----        | .18          | ---- |
| SO <sub>2</sub> .....                | trace       | ----         | ----         | ----        | ----         | ---- |
| P <sub>2</sub> O <sub>5</sub> .....  | .80         | trace        | .19          | ?           | .59          | ---- |
| CO <sub>2</sub> .....                | ----        | ----         | ----         | 1.82        | ----         | ---- |
| CuO .....                            | str. tr.    | ----         | ----         | ----        | ----         | ---- |
| NiO .....                            | .04         | ----         | ----         | ----        | ----         | ---- |
| CoO .....                            | str. tr.    | ----         | ----         | ----        | ----         | ---- |
| MnO .....                            | .22         | 1.20         | 1.18         | ----        | .13          | ---- |
| BaO .....                            | .50         | ?            | ?            | ?           | ?            | ---- |
| SrO .....                            | .16         | ?            | ?            | ?           | ?            | ---- |
| Cr <sub>2</sub> O <sub>3</sub> ..... | none        | ----         | ----         | ----        | ----         | ---- |
|                                      | <hr/> 99.73 | <hr/> 101.44 | <hr/> 100.38 | <hr/> 99.58 | <hr/> 100.08 |      |
| O=Cl .....                           | .01         |              |              |             |              |      |
|                                      | <hr/> 99.72 |              |              |             |              |      |

I. Leucitite, Bearpaw Mountain, Montana, H. N. Stokes anal.

II. Leucite basanite, Vesuvius 1631 (Trans. Roy. Irish Acad., vol. xxvi, p. 50, 1876), S. Haughton anal.

III. Leucite tephrite, *ibid* (*ibid*, p. 83), *ibid*.

IV. Leucitite, Leucite Hills, Wyoming (Emmons Surv. 40th Par., vol. ii, Descrip. Geol. 1877, p. 237), R. W. Woodward anal.

V. Leucite absarokite, Ishawooa Canyon, Wyoming (Hague, this Jour., vol. xxxviii, 1889, p. 47; Iddings, Jour. Geol., vol. iii, 1895, p. 938), J. E. Whitfield anal.

Ia. Molecular proportions of analysis I.

The marked features of this analysis are the low alumina and silica and the very high potash, peculiarities which sufficiently explain the presence of the leucite. Neglecting the very small amount of biotite and glass present, the essential minerals are iron ore, augite, and leucite, and considering the molecular proportions given in Ia these become

|                       |     |          |       |   |          |       |                                     |     |         |       |
|-----------------------|-----|----------|-------|---|----------|-------|-------------------------------------|-----|---------|-------|
| SiO <sub>2</sub> .264 | =2  | Diopside | 31.1% | Fe <sub>2</sub> O <sub>3</sub> .047=1<br>FeO .047=1 | Iron Ore | 11.8% | SiO <sub>2</sub> .511               | =4  | Leucite | 57.1% |
| CaO .132              | =1  |          |       |   |          |       | Al <sub>2</sub> O <sub>3</sub> .115 | =1  |         |       |
| MgO .118              | }=1 |          |       |   |          |       | Na <sub>2</sub> O .038              | }=1 |         |       |
| FeO .014              |     |          |       |   |          |       | K <sub>2</sub> O .092               |     |         |       |

Thus the analysis and the mineral composition agree in the most satisfactory manner. The iron ore is mostly present in the fine globulitic material which forms the main part of the base.

The presence of the water is difficult of explanation unless we consider a certain proportion of analcite present among the leucites. The rock appears absolutely fresh and unaltered, and the amount of glass base is entirely too small to contain it. Lindgren\* and Cross† have shown that analcite may be present in otherwise perfectly fresh unaltered rocks of high alkali content, and it is regarded by them as a primary component.

Analyses of other leucite rocks are given in the table for comparison, and it will be seen that the Bearpaw rock agrees most closely with the Vesuvian lavas: they are distinguished from it by higher amounts of lime and alumina and less of iron. The only two occurrences of leucitic rocks in this country of which we have analyses are given in Nos. 4 and 5, from which the present type varies considerably. It seems probable from the chlorine given in No. 5 that part of the leucite should really be referred to sodalite, and that 4 per cent. may be present.

The only other occurrence of leucite in America that we are aware of is the rock from Lower California described by von Chrustschoff,‡ though Kemp has shown that a dike in New Jersey should unquestionably be referred to leucite tephrite.§

The occurrence of pseudo-leucite is not here considered.||

\* Proceedings Cal. Acad. Sci., ser. 2, vol. iii, p. 51.

† Geol. Cripple Creek District, Colorado, p. 36. 16th Ann. Rept. Director U. S. G. S., Part II, p. 36, Washington, 1895.

‡ Tscher. Mitt., vol. 6, 1884, p. 160.

§ This Journal, vol. xlv, 1893, p. 298; *ibid.*, vol. xlvii, 1884, p. 339.

|| As this article was passing through the press, we have received the annual report of Dr. Hoffman (Geol. Surv. Canada, Part R, vol. vii, p. 13, 1896), in which he states that dark gray boulders containing large sub-translucent smoke-gray leucites have been found by Dr. G. M. Dawson, in the gravel of the Horsefly mine on Horsefly River, Cariboo Dist., Brit. Columbia. It is to be hoped that the Canadian geologists may be able to follow up this interesting occurrence.

ART. XVII.—*On the Composition and structure of the Hamblen County, Tennessee, Meteorite*; by GEORGE P. MERRILL.

THE meteorite described below was found in September, 1887, on a ridge about six miles W.S.W. from Morristown, Hamblen County, Tennessee, its meteoric nature being first recognized by Prof. J. M. Safford. Several fragments were discovered, the two larger weighing respectively 11 and 13 pounds, the aggregate weight of all about 36 pounds. Macroscopically the stone is dark gray, stained by oxidation of the iron, and sufficiently coarsely crystalline to allow a ready determination of the metallic iron and phenocrysts of pyroxene by the unaided eye. In composition and structure it varies greatly, at times the metallic portion prevailing in spongy masses enclosing the silicates, and again the silicates prevailing to the almost entire exclusion of the metal, or enclosing it only in the form of disseminated globules. According to the prevailing system, it will therefore have to be classed as a mesosiderite. Chemical analyses of the metallic and silicate portions, as made in the laboratories of the U. S. Geological Survey, are given below:\*

*Nickeliferous Iron.*

|    |       |
|----|-------|
| Fe | 90.92 |
| Ni | 7.71  |
| CO | .80   |
| Cu | trace |
| P  | .19   |
| S  | .04   |

99.66

*Stony Portions.*

## Soluble in HCl.

## Insoluble in HCl.

|                                | Soluble in HCl. |                             |                   | Insoluble in HCl. |                             |                   |
|--------------------------------|-----------------|-----------------------------|-------------------|-------------------|-----------------------------|-------------------|
|                                | Analysis.       | Calculated to 100 per cent. | Molecular ratios. | Analysis.         | Calculated to 100 per cent. | Molecular ratios. |
| SiO <sub>2</sub>               | 16.79           | 45.61                       | .760              | 31.47             | 50.67                       | .844              |
| Al <sub>2</sub> O <sub>3</sub> | 8.33            | 22.62                       | .222              | 9.25              | 14.89                       | .146              |
| Cr <sub>2</sub> O <sub>3</sub> |                 |                             |                   | .82               | 1.32                        | .009              |
| FeO                            | 4.88            | 11.73                       | .163              | 6.55              | 10.55                       | .147              |
| NiO                            | .39             | 1.06                        | .014              |                   |                             |                   |
| MnO                            |                 |                             |                   | .47               | .76                         | .010              |
| CaO                            | 5.19            | 14.09                       | .252              | 2.24              | 3.61                        | .064              |
| MgO                            | 1.34            | 3.64                        | .091              | 11.16             | 17.98                       | .449              |
| KO                             |                 |                             |                   | .02               | .03                         |                   |
| Na <sub>2</sub> O              |                 |                             |                   | .12               | .19                         | .003              |
| P <sub>2</sub> O <sub>5</sub>  | .46             | 1.25                        | .009              |                   |                             |                   |
| S                              | .25             |                             |                   |                   |                             |                   |
|                                | 37.63           | 100.00                      |                   | 62.10             | 100.00                      |                   |

\* Bulletin 113, U. S. Geological Survey, 1893, p. 61.



"In calculating the analysis of the soluble portion to 100 per cent the S and an amount of iron (.56 per cent FeO) sufficient to form FeS are first deducted."

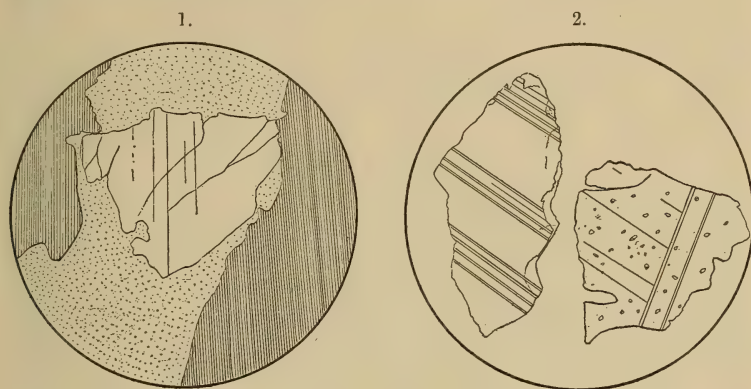
The present writer's attention was called to the stone by Mr. E. L. Preston of the Ward Natural History Establishment, who kindly offered to furnish material for the petrographic work. As will be noted by reference to the table, the chemical composition is somewhat peculiar, in that the percentage amount of soluble matter is so large (37.63 per cent), and yet, the amount of olivine, as indicated by the percentage of magnesia (1.34 per cent) is small. It was this feature of the analysis which first attracted Mr. Preston's attention. In the paper above referred to this peculiarity is recognized, but not satisfactorily explained. The statement is made that "in many stony meteorites olivine is a considerable constituent, generally forming the bulk of the soluble silicate; but in this case the analysis shows olivine to be present in but small proportions, if at all. It is interesting to see that both the soluble and insoluble portions have practically the same molecular ratios, the soluble portion reducing itself essentially to  $RAl_2SiO_6$ , in which  $R=Ca, Fe$ ; and the insoluble part to the same formula, where  $R=Mg, Fe$ ; both being equivalent to aluminous enstatite or pyroxene."

"At the time this analysis was made it was impracticable to supplement the work with the proper microscopical examination of sections, which doubtless, in conjunction with the chemical evidence, would have satisfactorily determined the minerals present. Without this microscopical knowledge, however, little that is definite can be said, except that there seem to be present two simular molecules, the one in which lime predominates being soluble, and the other, magnesian, being insoluble, in hydrochloric acid. The other alternative is to assume a complex molecule which is split into two sections by the action of the acid." That neither of these conclusions is even approximately correct appears in the results given below:

Three specific gravity determinations, made on fragments from 15 to 25 grms. in weight, including both iron and stony portions, yielded the present writer an average of 4.32.

In thin sections the structure of the stony portions is found to be holocrystalline granular, sometimes strongly cataclastic. This latter structure is particularly conspicuous in those portions rich in metallic iron, where the feldspars are often enclosed in the form of sharply angular fragments in the iron or in its numerous embayments, as shown in fig. 1. In the figure as drawn the heavily shaded portion is metallic iron, the colorless area anorthite and that finely dotted and granular silicates too badly stained to be drawn in outline. The appearance is not,

however, that of a clastic rock, but rather that of a crystalline variety which has been subjected to dynamic agencies. The structure as a whole is quite irregular, and as above noted porphyritic through the presence of large pyroxenes which at times are 5 to 8<sup>mm</sup> in diameter.



The groundmass of the stone is composed mainly of granules of pyroxenes and plagioclase, of such size as to render their determination by the microscope a matter of considerable ease, but which are interspersed with innumerable rounded and irregular granular forms so minute and so lacking in crystal outlines as to render their true mineralogical nature a matter of conjecture only.

The feldspars as a rule show polysynthetic twinning. Sections without twin striæ (and which are assumed to be approximately to  $\infty P \infty$ ) show the emergence of an optic axis just outside the field, and give extinction angles as high as  $-38^\circ$ , suggestive of anorthite. By means of a specific gravity solution a small quantity of the feldspars (0.19 grm.), was separated out and analyzed, with the results given below, and which confirm the result of the optical determination. They usually contain a large number of cavities and enclosures, as shown in fig. 2, in this respect, and with respect to their shattered condition as well, resembling those of the Sierra de Chaca stone.

*Feldspar out of Meteorite.*

|                                |       |         |
|--------------------------------|-------|---------|
| SiO <sub>2</sub>               | ----- | 42.02   |
| Al <sub>2</sub> O <sub>3</sub> | ----- | 37.77   |
| FeO                            | ----- | trace   |
| CaO                            | ----- | 16.41   |
| MgO                            | ----- | 0.96    |
| Na <sub>2</sub> O              | ----- | not det |
|                                |       | <hr/>   |
|                                |       | 97.16   |

Two pyroxenic minerals are present. The one of a gray color, owing to minute cavities and dust-like enclosures, and giving in all cases extinctions parallel and at right angles with the evident cleavage; microchemical tests show the presence of magnesia, but not of lime or alumina. It is hence assumed to be enstatite. The second is very clear and pellucid, of a faint greenish tinge, though without evident pleochroism. It shows an imperfect prismatic cleavage, a pronounced parting parallel to  $\infty P \frac{1}{\infty}$ , has at times somewhat fibrous or platy structure, and gives extinctions on  $\infty P \frac{\infty}{\infty}$ , measured against cleavage lines, running as high as  $30^\circ$ . Granules of this mineral isolated for microchemical tests were insoluble in hydrochloric acid. With fluorhydric acid, on a slide first covered with hard balsam, they dissolved, yielding abundant rhombs of magnesian fluosilicate. The solution treated with a drop of dilute sulphuric acid yielded gypsum needles, and with caesium chloride and sulphuric acid abundant minute, more or less modified octahedra of caesium alum. The mineral is therefore assumed to be diallage, though the angle of extinction is small. Olivine is quite inconspicuous, and were it not for the magnesia in the soluble portion of the stone, would be quite overlooked. It seems to exist, intergrown with the enstatite, and cannot be isolated. The powdered rock, after being passed repeatedly through a solution of sufficient density to separate the feldspar, still yields a small amount of gelatinous silica, the acid solution reacting for both magnesia and lime, suggesting the presence of monticellite. It is possible, however, that the lime may have come from inclosures of anorthite too small to be recognizable.

Repeated attempts were made at separating the two pyroxenes for complete analyses, but the variation in density was too slight to permit of this, even when the silver-thallium nitrate solution was employed.

Inasmuch as the presence of the minerals above noted, as determined microscopically, did not satisfy all the requirements of the analyses of the soluble portions, further qualitative and microchemical tests were resorted to. It was found that merely boiling the pulverized stone for a few minutes in distilled water was sufficient to give a solution reacting for chlorine, sulphuric acid, lime and iron. These reactions considered in connection with the minerals known to occur in meteorites, are sufficient to suggest, if not prove, the presence of gypsum, as an oxidation product of oldhamite, and of lawrencite. The phosphoric acid suggests schreibersite, and the odor of sulphuretted hydrogen given off by the boiling solution, troilite. Instead of, then, attempting to account for the results of the analyses on the assumed presence of two minerals having practically the same molecular ratios, as was done



in the paper above quoted, the present writer would suggest the following as the probable mineral nature of the stone, including the metallic portion.

- (1) Nickeliferous iron.
- (2) Enstatite.
- (3) Diallage.
- (4) Anorthite.
- (5) Olivine (or monticellite).
- (6) Oldhamite (or secondary gypsum).
- (7) Lawrenceite.
- (8) Troilite.
- (9) Schreibersite.

According to the prevailing system of classification the stone must be called a mesosiderite; viewed from the standpoint of terrestrial petrography, it would be classed as a gabbro with gradations toward pyroxenite.

A few words more may well be written concerning the structure of the stone. This, as above noted, is crystalline granular throughout, no glass whatever being detected. In the finer-grained siliceous portions the constituents have undoubtedly all originated by crystallization in the positions they now occupy and have not suffered at all from dynamic agencies. The coarser portions of the rock, and particularly those in immediate juxtaposition with the metallic iron, have a strongly marked cataclastic structure, the feldspars existing mainly as angular fragments, as shown in fig. 2. All structural features point to the injection of the metallic iron, or at least to its reduction to the metallic state, subsequently to the solidification of the stone, the same being accompanied by a shattering and more or less displacement of the minerals in the near vicinity. In the more siliceous portions the iron exists only in small round blebs, and seems to have been wholly without effect on the structural features; but where existing in masses of some size, as in fig. 1, the appearance is at once suggestive of subsequent injections and consequent disruption of particles.

The occurrence of the feldspars to the exclusion of the enstatites in the immediate vicinity of the metallic portions, would be extremely suggestive could we consider both as products of solidification in place, from an iron-bearing magma, in the one case the elements combining to form an iron rich silicate (enstatite), and in the other, metallic iron and feldspar. The extremely fragmental condition of the feldspars, particularly when closely associated with the iron, suggests, however, that these were in a crystalline condition prior to the injection of the metallic portions, and hence that no such extreme phase of magmatic differentiation could have taken place.

It should be noted that the stone, as shown by sections cut from different fragments, is quite variable, both in structure and in the relative proportions of its constituent minerals.

ART. XVIII.—*Wardite: a New Hydrous Basic Phosphate of Alumina*; by JOHN M. DAVISON.

[Read before the Rochester Academy of Science on April 28, 1896.]

IN the number of this Journal for April, 1894, Mr. Packard describes and gives the analysis of massive variscite from Utah. Since then a considerable quantity of this mineral has been received by Ward's Natural Science Establishment, of Rochester, N. Y. It is in form of nodules and shows the mineral in several shades of green, and one specimen of pure milk-white color. Nearly all have the firm brownish-yellow outer coating and some show the variscite, altered to a softer whitish mineral, as described by Mr. Packard.

Occasionally decomposition of the variscite has left cavities in the nodules, and encrusting these cavities is an hydrous basic phosphate of alumina, which does not appear to have been hitherto described. It is of light green or bluish-green color, with vitreous luster, concretionary structure, hardness greater than variscite,—about 5—and specific gravity 2·77. Its concentric habit has, in places, developed an oolitic structure, resembling clusters of fine shot with rough surface. Tiny balls are found on the surface of the larger masses. A thin section shows that they have been buried in the mineral at all stages of its growth, giving a mottled appearance to the section.

Analysis of this mineral gave:

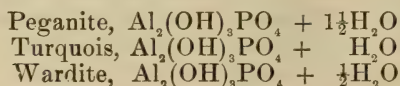
|  |       |
|--|-------|
| P <sub>2</sub> O <sub>5</sub> .....                  | 34·46 |
| FeO .....  | 0·76  |
| CuO .....  | 0·04  |
| MgO .....  | 2·40  |
| Na <sub>2</sub> O .....                              | 5·98  |
| K <sub>2</sub> O .....                               | 0·24  |
| H <sub>2</sub> O .....                               | 17·87 |
| Al <sub>2</sub> O <sub>3</sub> (by difference) ..... | 38·25 |

---

100·

The formula may be written: P<sub>2</sub>O<sub>5</sub>·2Al<sub>2</sub>O<sub>3</sub>·4H<sub>2</sub>O, or Al<sub>2</sub>(OH)<sub>3</sub>PO<sub>4</sub> +  $\frac{1}{2}$ H<sub>2</sub>O, or perhaps AlNaPO<sub>4</sub>·Al(OH)<sub>3</sub>· $\frac{1}{2}$ H<sub>2</sub>O.

This mineral, to which I would give the name of *Wardite*, in honor of Prof. Henry A. Ward, of Rochester, N. Y., would seem to come in series with



Before the blowpipe it swells, cracks open, rounds and turns white, giving a sodium flame. Yields water in the closed tube; gives hydrogen phosphide with the magnesium test; turns blue with cobalt nitrate. With borax in O. F. gives a clear bead; yellow, hot; colorless when cold, with perhaps a tinge of green if highly charged; opaque by flaming if saturated. When ignited it sinters. Partly decomposed by acids. Finely powdered and strongly heated with con.  $\text{HCl}$  or  $\text{HNO}_3$  about 20 per cent. remained undissolved. This residue on ignition was pure white and entirely dissolved on further treatment with acid. But if the mineral was first ignited and then heated with acids, about 11 per cent. remained undissolved. This residue, on ignition, was white with a pinkish tinge and resisted further action of acids.

In course of this investigation analyses of variscite were made which closely agreed with those given by Mr. Packard. They did not, however, confirm the statement that, before ignition, variscite is insoluble in acids. When finely powdered and strongly heated for some time, it completely dissolved in either  $\text{HCl}$ ,  $\text{HNO}_3$ , or  $\text{H}_2\text{SO}_4$ —perhaps most easily in the last. Heated in fine powder for 40 hours to 100-130 C. variscite gave off 22.22 per cent. water, then over the blast-lamp for 30 minutes lost 0.50 more.

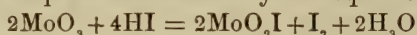
One interesting specimen shows the green variscite with its lower surface changed to a yellow alteration-product. On top, and seemingly running into the green, is a colorless radiate rosette, strongly resembling wavellite, but with rather stouter prisms. Imbedded in this rosette is a concentric mass of wardite, differing in form and color from both the variscite and the radiate mineral. Attached to another piece of superficially altered variscite was a nodule of the size and shape of a pea, itself covered with the same alteration product. Detached, it was found concentric in structure, having both white and colorless layers and hard enough to defy the point of a knife. It looked like chalcedony, but the alteration zone showed that it probably was amphithalite.



ART. XIX.—*The Iodometric Estimation of Molybdic Acid*;  
by F. A. GOOCH and CHARLOTTE FAIRBANKS.

[Contributions from the Kent Chemical Laboratory of Yale University—LII.]

I. *The Digestion Method*.—Mauro and Danesi have shown\* that under carefully regulated conditions, hydrochloric acid, potassium iodide and a soluble molybdate interact so definitely that the iodine set free from an excess of potassium iodide may be taken as a measure of the molybdic acid, assuming that every molecule of molybdic acid sets free an atom of iodine. They explain this action by the equation :



These results are obtained by acting upon a soluble molybdate containing from 0.1 to 0.5 grm. of molybdic acid with 1.5 grm. of potassium iodide in 1.5<sup>cc</sup> of water and 2.5<sup>cc</sup> of strong hydrochloric acid, in an atmosphere of carbon dioxide, the whole being heated an hour and a half in a sealed tube. The authors point out that with prolonged heating the action proceeds a little farther, and in the cold, under conditions otherwise similar, not quite so far as the theory of the equation would indicate.

Upon following out exactly the directions of Mauro and Danesi we obtained results similar in general to theirs. The digestion in sealed tubes under the conditions indicated gave results closely comparable with theirs, and these were in fairly good accord with the theory of the reduction. Our results obtained by digesting in the cold and in small volumes for a long time, according to the second method of Mauro and Danesi, were not equally favorable, and these results, as well as those obtained by varying the treatment, indicated an increasing difficulty in the reduction of the molybdic acid as its amount increased. As will be seen from the table, the method of Mauro and Danesi was varied in two ways: instead of only treating in small volumes (4<sup>cc</sup>) at 100° C., we used larger volumes (20<sup>cc</sup> to 30<sup>cc</sup>) at 100° C. with weaker acid and smaller amounts of the iodide; and instead of their treatment in the cold of only small volumes (4<sup>cc</sup>), large volumes (50<sup>cc</sup> to 100<sup>cc</sup>) with stronger acid were used.

*Treatment in sealed tubes at 100° for 1½ hours.*

(Method of Mauro and Danesi.)

MoO<sub>3</sub>, as ammonium

| HCl. | H <sub>2</sub> O. | KI.  | molybdate. | MoO <sub>3</sub> found. | Error. |
|------|-------------------|------|------------|-------------------------|--------|
| cc.  | cc.               | grm. | grm.       | grm.                    | grm.   |
| 2.5  | 1.5               | 1.5  | .1010      | .1007                   | .0003— |
| 2.5  | 1.5               | 1.5  | .3015      | .3004                   | .0007— |
| 2.5  | 1.5               | 1.5  | .5006      | .4795                   | .0031— |
| 2.5  | 1.5               | 1.5  | .5020      | .4924                   | .0096— |

\* Zeitschr. für Anal. Chem., 1881.

*Treatment 18-22 hrs. in cold.*

(Method of Mauro and Danesi.)

| HCl.<br>cc. | H <sub>2</sub> O.<br>cc. | KI.<br>gram. | MoO <sub>3</sub> as above.<br>gram. | MoO <sub>3</sub> found.<br>gram. | Error.<br>gram. |
|-------------|--------------------------|--------------|-------------------------------------|----------------------------------|-----------------|
| 2.5         | 1.5                      | 1.5          | .0986                               | .0982                            | .0004—          |
| 2.5         | 1.5                      | 1.5          | .0982                               | .0979                            | .0003—          |
| 2.5         | 1.5                      | 1.5          | .2041                               | .2024                            | .0017—          |
| 2.5         | 1.5                      | 1.5          | .2059                               | .2043                            | .0016—          |
| 2.5         | 1.5                      | 1.5          | .2063                               | .2040                            | .0023—          |
| 2.5         | 1.5                      | 1.5          | .3116                               | .3059                            | .0057—          |
| 2.5         | 1.5                      | 1.5          | .3098                               | .3011                            | .0087—          |
| 2.5         | 1.5                      | 1.5          | .4080                               | .4011                            | .0069—          |
| 2.5         | 1.5                      | 1.5          | .4087                               | .4015                            | .0072—          |
| 2.5         | 1.5                      | 1.5          | .5210                               | .5102                            | .0108—          |
| 2.5         | 1.5                      | 1.5          | .5172                               | .5023                            | .0149—          |

*Treatment at 100° for 1 hour.*

(Amounts of liquid and iodide different from those of Mauro and Danesi.)

| HCl.<br>cc. | H <sub>2</sub> O.<br>cc. | KI.<br>gram. | MoO <sub>3</sub> taken.<br>gram. | MoO <sub>3</sub> found.<br>gram. | Error.<br>gram. |
|-------------|--------------------------|--------------|----------------------------------|----------------------------------|-----------------|
| 15          | 15                       | .5           | .0893                            | .0897                            | .0004+          |
| 15          | 15                       | .5           | .0824                            | .0813                            | .0011—          |
| 15          | 15                       | .5           | .0828                            | .0813                            | .0015—          |
| 15          | 15                       | .5           | .0990                            | .0982                            | .0008—          |
| 10          | 10                       | .5           | .0841                            | .0842                            | .0001+          |
| 10          | 10                       | .5           | .1683                            | .1591                            | .0092—          |
| 10          | 10                       | .5           | .1706                            | .1536                            | .0170—          |
| 20          | 20                       | .5           | .1695                            | .1633                            | .0062—          |

*Treatment 18 hours in cold.*

(Amounts of liquid different from those of Mauro and Danesi.)

| HCl.<br>cc. | H <sub>2</sub> O.<br>cc. | KI.<br>gram. | MoO <sub>3</sub> taken.<br>gram. | MoO <sub>3</sub> found.<br>gram. | Error.<br>gram. |
|-------------|--------------------------|--------------|----------------------------------|----------------------------------|-----------------|
| 40          | 10                       | 1.5          | .5018                            | .4847                            | .0171—          |
| 90          | 30                       | 1.5          | .5005                            | .4910                            | .0095—          |
| 75          | 25                       | 1.5          | .5035                            | .4934                            | .0101—          |
| 75          | 25                       | 1.5          | .5022                            | .4920                            | .0102—          |

The explanation of these experimental results we were inclined to believe lay in a tendency on the part of the iodine, set free in the process, to reverse the action. If this is so, the obvious remedy should be found in the removal of the iodine from the sphere of action, and this idea led us to experiment upon a process of distillation in which the iodine should be collected and estimated in the distillate; but before our work was completed, Friedheim and Euler published\* the results of their investigation along the same line.

II. *Distillation Process.*—These investigators have shown that if molybdic acid is treated with potassium iodide and

\* Berichte d. d. Chem. Gesell., xxviii, 2066.

hydrochloric acid, one atom of iodine is distilled for every molecule of molybdic acid present. The process according to their directions consists in treating in the Bunsen apparatus from 0.2 to 0.3 grm. of a soluble molybdate, or molybdic acid dissolved in sodium hydroxide, with 0.5 grm. to 0.75 grm. of potassium iodide and enough hydrochloric acid (sp. gr. 1.12) to two-thirds fill the flask. The solution is warmed for some time and only heated to boiling when the flask is wholly filled with the heavy vapor of iodine. It is boiled until no more iodine is visible and the liquid is of a clear green color. The iodine, collected in a receiver previously charged with a solution of potassium iodide, is then titrated with a standard thiosulphate solution. Results, varying between .05 per cent and 1.3 per cent on amounts, ranging from 0.2 grm. to 0.4 grm., of the molybdic acid present, were obtained by them.

Our experience fully confirms the usefulness of the method of Friedheim and Euler, but we have found it necessary to define more exactly the conditions of distillation. It is not sufficient to say that the boiling shall be stopped when a clear green color appears and when the steam is no longer colored by iodine; for the green color comes very gradually and we have repeatedly found iodine in the residue after the green color had developed distinctly. We have found it safer and more convenient to start the distillation with a definite volume of liquid and boil until the volume is reduced to a definite point.

Our work has shown that if the initial volume is about 40<sup>cc</sup>, no iodine remains in the flask after the liquid has been boiled down to 25<sup>cc</sup>; and that at that degree of concentration the molybdic acid shows the theoretical reduction; but if the concentration is pushed beyond this point, a tendency to further reduction of the molybdic acid becomes evident.

We find it necessary to carry on the distillation in an atmosphere of carbon dioxide, inasmuch as the hydriodic acid freed by the action of hydrochloric acid of the strength employed upon the potassium iodide, is decomposed by distillation in contact with air, with liberation of iodine. As even a trace of oxygen will immediately set free iodine from boiling hydriodic acid, the carbon dioxide must be as free as possible from oxygen. The carbon dioxide which we used was evolved from boiled marble by the action of boiled acid to which a little cuprous chloride had been added, and was finally passed through a solution of iodine in potassium iodide to free it from any reducing substance which might be present.

The apparatus which we found most satisfactory was constructed with sealed and ground joints exclusively, and is shown in the accompanying figure. The distillation takes place in the first flask, and the iodine collects in the second flask and trap, which hold a solution of potassium iodide kept cool by immersion of the flask in cold water.





| MoO <sub>3</sub> dissolved<br>in NaOH.<br>gram. | KI.<br>gram. | MoO <sub>3</sub> found.<br>gram. | Error.<br>gram. |
|---|--------------|----------------------------------|-----------------|
| ·2273   | 0·5          | ·2281                            | ·0008 +         |
| ·2052   | 0·5          | ·2062                            | ·0010 +         |
| ·3474   | 0·5          | ·3467                            | ·0007—          |

III. *Reoxidation Process*.—It was noticed during our experiments upon the method of Mauro and Danesi, as has been remarked previously, that large amounts of iodine in the digestion flask seemed to react upon the reduced product. In the process of Friedheim and Euler, too, it was discovered that, when the iodine which had collected in the second flask was drawn back into the first flask and mixed with the hot reduced product, the iodine found by titration was deficient in amount. It was found also that small amounts of standard iodine, introduced into the flask containing the reduced molybdic acid in an atmosphere of carbon dioxide, were absorbed slowly when this mixture was heated. This slow disappearance of the iodine in acid solution suggested the possibility of effecting the complete oxidation of the reduced molybdic acid in an alkaline solution, containing a tartrate or other salt of an organic acid to prevent precipitation. Several experiments were made in this direction upon the residues left in the process of Friedheim and Euler, the distillate having been titrated as usual with sodium thiosulphate to make sure that the reduction had proceeded properly. These residues were treated in each case with 1 gram. of tartaric acid, neutralized by acid sodium carbonate and left standing for an hour or two with an excess of standard iodine. Upon determining, by means of standard arsenious acid, the iodine left over, it was found that the amount of it which had disappeared corresponded very closely with that set free in the distillation, which is of course the same as that necessary to reoxidize the molybdic acid completely.

The conditions necessary to complete oxidation being known, experiments were made to see whether the process could not be successfully carried on in an open flask. Naturally under these conditions the air present must, as in the previous experiments, tend to set free some iodine at the outset, but, inasmuch as the hydriodic acid gradually diminishes in strength as the molybdenum is reduced and all iodine is ultimately driven from the flask, which is filled with steam during the boiling, it seemed possible that the danger from the action of atmospheric oxygen might be so far reduced as not to interfere essentially in the estimation of the molybdenum in the residue, provided the contents of the flask is diluted and cooled at the end of the boiling. Ammonium molybdate containing from 0·1 to 0·3 gram. molybdic acid, 0·5 gram. of potassium iodide,

20<sup>cc</sup> of water and 20<sup>cc</sup> of hydrochloric acid (sp. gr. 1.20)—the same proportions as those used in the process of Friedheim and Euler—were put into a 100<sup>cc</sup> flask or narrow-based Erlenmeyer, and boiled from a total volume of 40<sup>cc</sup> to exactly 25<sup>cc</sup>, a point carefully marked on the flask. At this point of concentration, tests, repeated in many cases, have shown no free iodine in the reduced solution. If the solution is boiled below 25<sup>cc</sup>, there is a tendency for the reducing action to go too far.

The residue was diluted at once, neutralized with acid sodium carbonate, and treated with an excess of standard iodine.

For a trap to prevent loss during boiling, a two-bulbed calcium chloride tube, cut off as shown in the figure four centimeters below the larger bulb, was fitted loosely inside the neck of the flask. Too violent boiling was prevented by the addition of two or three small pieces of pumice stone. While still acid the reduced solution, diluted and containing at this time little hydriodic acid, is not appreciably reoxidized in the air for some time; but when once made alkaline, it is very easily changed. Therefore the iodine for reoxidation must either be added before the solution is made alkaline or great care must be taken while neutralizing to stir the solution as little as possible and to draw in the iodine immediately. Less chance for error is introduced if the reduced solution is put, with an excess amounting to at least 8<sup>cc</sup> of decinormal iodine and with a gram of tartaric acid, to prevent precipitation, in a liter flask, corked and then neutralized with acid sodium carbonate. The flask was fitted with a paraffined rubber stopper, carrying a funnel with a stop-cock for introducing the acid sodium carbonate and a Will and Varrentrapp trap for catching in a solution of potassium iodide any iodine thrown off during the effervescence. In some of the test experiments normal potassium carbonate, as causing less effervescence, was substituted for the acid sodium carbonate during the first part of the neutralization; the solution, however, must always finally be made alkaline with the acid carbonate.

The simpler method of neutralization is to put the reduced solution and a gram of tartaric acid in a liter flask, adding enough sodium hydroxide to nearly neutralize the solution, and finally making the solution surely alkaline with acid sodium carbonate. An excess of the standard iodine must be drawn in at once or atmospheric oxidation will take place and the error of the process be great.

If the solution has been properly neutralized according to either method, the iodine color should perceptibly fade within





fifteen minutes, but for complete oxidation the trapped or corked bottle should be set aside out of sunlight for an hour and a half or two hours. The iodine which was not used for reoxidation was then titrated with a standard arsenic solution. Since there is a slight tendency, especially when sodium hydroxide and acid sodium carbonate are used for neutralization, toward the formation of a little iodate, it is wise to acidulate the solution in each case slightly with dilute hydrochloric acid and then to determine by sodium thiosulphate the iodine which has taken the form of iodate. The ratio 126.85:144 expresses the relation of the total amount of iodine used in the reoxidation process to the calculated amount of molybdic acid present. The table given below shows the amount of molybdic acid taken in the form of ammonium molybdate and the molybdic acid found calculated from the iodine used in reoxidation.

| MoO <sub>3</sub> as<br>ammonium<br>molybdate,<br>grm. | KI.<br>grm. | MoO <sub>3</sub><br>found,<br>grm. | Error.<br>grm. | Neutralized by                                      |
|---|-------------|------------------------------------|----------------|---|
| 1640  | .5          | .1639                              | .0001—         | K <sub>2</sub> CO <sub>3</sub> + NaHCO <sub>3</sub> |
| 1692  | .5          | .1681                              | .0011—         | “ “   |
| 1666  | .5          | .1661                              | .0005—         | “ “   |
| 1517  | .5          | .1517                              | .0000          | NaHCO <sub>3</sub>                                  |
| 2530  | .5          | .2537                              | .0007+         | “   |
| 1636  | .5          | .1637                              | .0001+         | “   |
| 1702  | .5          | .1702                              | .0000          | “   |
| 1520  | .5          | .1518                              | .0002—         | “   |
| 1642  | .5          | .1652                              | .0010+         | “   |
| 4560  | .75         | .4560                              | .0000          | “   |
| .1690   | .5          | .1683                              | .0007—         | NaOH + NaHCO <sub>3</sub>                           |
| .0507   | .5          | .0519                              | .0012+         | “ “   |
| .1663   | .5          | .1666                              | .0003+         | “ “   |
| .0101   | .5          | .0095                              | .0006—         | “ “   |
| .1639   | .5          | .1632                              | .0007—         | “ “   |
| .1636   | .5          | .1625                              | .0011—         | “ “   |
| .0507   | .5          | .0510                              | .0003+         | “ “   |
| .1685   | .5          | .1683                              | .0002—         | “ “   |
| .1514   | .5          | .1512                              | .0002—         | “ “   |
| .1649   | .5          | .1646                              | .0003—         | “ “   |

Average error in the experiments, — .0001 gram.

The results given in the foregoing table show that molybdic acid can be determined with accuracy and convenience by boiling it with hydrochloric acid and a small excess of potassium iodide to a definite concentration in an ordinary flask, then neutralizing the residue with acid sodium carbonate, and reoxidizing the reduced molybdic acid with standard iodine.

ART. XX.—*On the Existence of Selenium Monoxide*; by  
A. W. PEIRCE.

[Contributions from the Kent Chemical Laboratory of Yale University—LIII.]

It was Berzelius's idea that the odor of decayed cabbage which is noticed when selenium is burned in air is due to the formation of a gaseous lower oxide of selenium which he called the monoxide. The same oxide is said to be formed when selenium sulphide is dissolved in an insufficient amount of aqua regia, in the distillation of a mixture of selenium and selenium dioxide, and in the action of sulphur upon selenium dioxide.

Sacc\* records his inability to obtain such an oxide, and attributes the odor which is noticed under these conditions to a trace of selenium hydride. A very minute trace of the hydride is sufficient to develop a very considerable odor, and traces of moisture may be enough to produce a perceptible odor of the hydride when the conditions are favorable to action upon the elementary selenium. When selenium burns in air, or when its sulphide is oxidized by aqua regia, moisture is inevitably present, and when selenium dioxide is reduced by sulphur or intermixed with elementary selenium its extremely hygroscopic character implies the presence of traces of water.

It has been a generally accepted opinion of late that the selenium monoxide does not exist, but more recently, in work upon certain organic compounds of selenium, Chabrié has been led to the idea that the monoxide does exist and that it is a solid body. Chabrié states† that when selenium is heated in air it tends to increase in weight. At 100° C. the increase is said to be inappreciable, but at 180° C. it approaches very nearly to the limit corresponding to the formation of the selenium monoxide,  $\text{SeO}$ . Further he says that this increase in weight when the selenium is heated to 180° cannot be due to the formation of the dioxide, since that compound, if it were formed, could be seen as a crystalline deposit; or if the temperature is too high to allow it to deposit, a loss of weight would result. He is so sure of the increase that, were it not for the fact that the monoxide has not been generally recognized, he would suggest as a possible means for the determination of selenium to heat it to 180° and estimate it as  $\text{SeO}$ . The selenium with which Chabrié obtained these results was reduced by acting with sodium sulphite and hydrochloric acid upon the product of oxidation of certain organic compounds of selenium of the

\* *Annales de Chimie et de Physique* III, xxi, 119.† *Ibid.*, VI, xx, 273.

aromatic series by means of nitric acid, and filtering on glass wool. The product when dried quickly at 100° gave results in accord with his theory of the constitution of the compounds, counting the selenium dried at 100° as existing in elementary form. Thus:

|                    | I.      | II.     | III.    |
|--------------------|---------|---------|---------|
| Se found .....     | 0·0347  | 0·0680  | 0·0406  |
| Se by theory ..... | 0·0349  | 0·0678  | 0·0414  |
|                    | <hr/>   | <hr/>   | <hr/>   |
|                    | 0·0002— | 0·0002+ | 0·0008— |

In other analyses of the same compounds, in which the selenium was dried at 180° instead of at 100°, the weight of the selenium was so much greater as to suggest the idea that the element had oxidized to the condition of the monoxide.

Thus:

|                  | I.     | II.     | III.    | IV.     |
|------------------|--------|---------|---------|---------|
| SeO (?) found... | 0·0301 | 0·0525  | 0·0523  | 0·0517  |
| SeO by theory... | 0·0301 | 0·0517  | 0·0504  | 0·0498  |
|                  | <hr/>  | <hr/>   | <hr/>   | <hr/>   |
|                  | 0·0000 | 0·0008+ | 0·0019+ | 0·0019+ |

Had Chabrié actually found that the same identical selenium determined by drying to a constant weight at 100°, did actually increase in weight at 180° to a constant amount corresponding exactly to what the weight should be were the monoxide formed, the evidence of such oxidation would be good. What Chabrié did, however, was to show that when the selenium from one sample of his compound was dried at 100° and regarded as elementary selenium, the amount of it found corresponded to his theory of the composition of his compound; while to harmonize the results of analysis with the demands of the theory, when the selenium from another sample of the same preparation was heated to 180° it became necessary to assume that the selenium had been oxidized to the condition of the monoxide. Moreover, it has been shown very recently by Krafft and Kaschau\* that the composition and constitution given by Chabrié to some, at least, of his organic compounds of selenium cannot be sustained. It has seemed to be desirable, therefore, to put the question of the oxidation of selenium at 180° to the direct test.

I have dried selenium to a constant weight at 100° C. and then have heated it to 180° C. for various periods of time, and in no single case have I observed the slightest increase in weight. In the following table are the results of these experiments. In every case the selenium was taken originally as the

\* Ber. d. d. Chem. Gesell., xxix, 428.



dioxide, prepared as described in previous articles, and precipitated in some cases with sulphurous acid, in some instances with potassium iodide, dried to a constant weight at 100° and then heated to the temperature and for the periods indicated below :

| Exp. | Se found<br>at 100°.<br>gram. | Temp. | Time.              | Weight.<br>gram. | Loss.<br>gram. |
|------|-------------------------------|-------|--------------------|------------------|----------------|
| 1.   | 0·0356                        | 110°  | $\frac{1}{2}$ hour | 0·0350           | 0·0006         |
|      |                               | 130°  | $\frac{1}{2}$ "    | 0·0348           | 0·0002         |
| 2.   | 0·0355                        | 110°  | $\frac{1}{2}$ "    | 0·0350           | 0·0005         |
|      |                               | 130°  | $\frac{1}{2}$ "    | 0·0347           | 0·0003         |
|      |                               | 150°  | $\frac{1}{2}$ "    | 0·0346           | 0·0001         |
| 3.   | 0·0576                        | 180°  | 8 $\frac{1}{2}$ "  | 0·0546           | 0·0030         |
| 4.   | 0·0576                        | 180°  | 8 $\frac{1}{2}$ "  | 0·0558           | 0·0018         |
| 5.   | 0·3324                        | 180°  | 2 "                | 0·3306           | 0·0018         |
| 6.   | 0·3500                        | 180°  | 1 $\frac{1}{2}$ "  | 0·3445           | 0·0055         |
| 7.   | 0·4274                        | 180°  | 1 $\frac{1}{2}$ "  | 0·4232           | 0·0042         |

Other experiments were made for the purpose of determining if possible just how the losses occur. The selenium collected as usual upon asbestos in a perforated crucible was introduced into a large glass tube placed horizontally in an air bath in such manner that the tube extended outside the bath at both sides and remained cool at the ends. A current of dry air was drawn through ignited asbestos and then through the tube containing the selenium and crucible, and passed to the suction pump through a glass trap filled with water. A thermometer placed within the tube and closely adjacent to the selenium showed the temperature of the selenium as the experiment progressed. On gradually heating the bath no change was observed at first, but at 180° C. a mirror of red elementary selenium formed on the cooler portions of the tube outside the bath, but did not extend so far as the trap. At the end of the heating the crucible was weighed and the loss determined. The washings of the tube and the trap when acidified and tested with potassium iodide gave no indication of selenious acid, as would inevitably be the case if selenium dioxide were formed and volatilized during the heating. The loss is due, therefore, entirely to the volatilization of the selenium as such.

| Exp. | Se found<br>at 100°. | Temp. | Time.                 | Weight. | Loss.   |
|------|----------------------|-------|-----------------------|---------|---------|
| 8.   | 0·0706               | 180°  | 2 $\frac{1}{2}$ hours | 0·0628  | 0·0078  |
| 9.   | 0·0987               | 180°  | 1 $\frac{3}{4}$ "     | 0·0948  | 0·0039* |
| 10.  | 0·3192               | 180°  | 4 "                   | 0·3121  | 0·0071  |
| 11.  | 0·0983               | 180°  | 3 $\frac{3}{4}$ "     | 0·0925  | 0·0049  |
|      |                      | 200°  | 2 "                   | 0·0876  | 0·0058  |

\* In current of CO<sub>2</sub> instead of air.

In every case, irrespective of the reducing agent employed or details of treatment, I get a loss of weight on heating selenium in air to  $180^{\circ}$ , due to the volatilization of the selenium. If this is so, it should be possible to so arrange the apparatus that the selenium volatilized may be caught and weighed.

A drying tube with ground-in stopper was, therefore, sealed to a smaller tube carrying a bulb filled with ignited asbestos. The selenium was weighed and introduced upon an asbestos felt into the larger tube and the whole was carefully weighed.

The larger tube was heated in the air bath, while air was drawn through the tube in the direction of the bulb of asbestos, which was outside the bath and cool. Selenium volatilized as before, very evidently, as far as the asbestos in the bulb, where it was caught. On cooling and weighing the tube and contents, absolutely no change of weight was observed. This shows that no gaseous product is formed to occasion the loss, but that the decrease of weight in the former experiments was due to the volatilization of the selenium itself.

Thus I am unable to duplicate the results of Chabrié in this matter, although I have followed his method of treatment so far as it is described. The only difference apparent is in the source of the selenium—in this work the dioxide of known purity with which much exact work has recently been done, and in Chabrié's work the oxidation product of certain organic compounds. I fail to see, however, how this difference in origin can affect the sensitiveness of the selenium with reference to the oxidizing action of the air.

Having thus been unable to obtain the monoxide in the solid state, I have made some experiments upon the oxidation of selenium by heating it in mixture with dioxide and under such conditions that the existence of a gaseous product, such as Berzelius describes it to be, would be noted, even if it were formed in very small amount.

A hard glass tube of convenient size, about 2<sup>cm</sup> in diameter and 65<sup>cm</sup> in length, was washed and dried most carefully and sealed at one end. Through the open end were introduced 0.0247 gm. pure selenium dioxide, freshly prepared and scrupulously protected against moisture, and 0.0250 gm. powdered selenium. The open end was then drawn out in such a way that attachment could easily be made to an air pump and an intervening portion of the tube constricted so as to be easily sealed later. The end was attached to a mercury air pump and the pressure reduced to 4<sup>mm</sup>. By applying a flame to the constricted part the tube was sealed in that condition. The tube was heated gradually in a small combustion furnace until the whole contents were vaporized, maintained in that condition some

minutes and then cooled. At every opportunity of lower temperature the selenium vapors would condense into dark metallic drops which ran into larger and larger drops, like mercury globules, seeming to separate from the dioxide vapors. This treatment was repeated six times at intervals, the contents of the tube showing each time the same phenomena of sublimation and condensation. Nothing was observable at any time to indicate chemical change in either substance, each maintaining the characteristics of its own sublimation.

Finally the air pump was again attached and allowed to work until the manometer registered no pressure. Upon breaking the end of the tube by pinching it inside the rubber connector, the height of the mercury column indicated the same pressure as when the tube was originally sealed. When disconnected the tube possessed not the slightest odor.

This experiment was repeated with the sole modification that the heating was not carried to a temperature so high, and this time 0.0730 gm. freshly prepared dry selenium dioxide and 0.0730 gm. powdered selenium were sealed up in the evacuated tube and heated for seven hours at 180° C. and finally for one hour at 200°. Upon breaking the tube under conditions similar to those of the previous experiment the contents showed no pressure and possessed no odor. Obviously no gaseous product was formed under these conditions.

I have thus been unable to find evidence of the existence of selenium monoxide, either gaseous or solid, and my experience goes to show that the peculiar smell attributed by Berzelius to the monoxide is only developed, as Sacc found, when selenium is heated in presence of moisture, and that a mere trace of moisture is sufficient to produce the odor.

In conclusion I wish to express my thanks to Prof. F. A. Gooch for many valuable suggestions during this work.



## SCIENTIFIC INTELLIGENCE.

## II. GEOLOGY AND MINERALOGY.

1. *Anticlinorium and Synclinorium*.—Questions of nomenclature in science are of course altogether subordinate to questions of fact or principle. They are, nevertheless, by no means unimportant. Two propositions in regard to nomenclature command, I think, general acceptance: first, a name already introduced ought not, save in most exceptional cases, to be employed in a different sense from that in which it was originally employed; secondly, when a new word is introduced, or when an old word (in the exceptional cases in which such procedure is justifiable) is employed in a new sense, the word ought to be etymologically appropriate to the meaning assigned.

For both of these reasons, it seems to be matter for regret that Professor Van Hise, in his masterly discussion of Folds,\* in the *Journal of Geology* for April-May, has seen fit to use the words "anticlinorium" and "synclinorium" in the sense respectively of composite anticline and composite syncline. As correctly stated by Professor Van Hise, the words "anticlinorium" and "synclinorium" were first used by the late Professor James D. Dana. They were, however, used by Professor Dana in a very different sense from that in which Professor Van Hise now proposes to employ them. The paper in which they were first published was entitled, "On Some Results of the Earth's Contraction from Cooling, including a Discussion of the Origin of Mountains, and the Nature of the Earth's Interior;" and was published in this *Journal* for June, 1873.† In that article, Professor Dana expounded his well-known view, that, in the great majority of cases, a mountain range is formed by the crushing of the thick mass of strata which have slowly accumulated during the progressive subsidence of a great geosyncline. Such a mountain range he proposed to call a synclinorium, the latter half of the word being derived from the Greek *ὄρος*, a mountain. The word therefore expressed very appropriately the conception of a mountain range made out of the material accumulated in a great synclinal depression.

In the same article, Professor Dana called attention to the fact that, in some instances, an elevation of land so great and so permanent as to deserve recognition as a mountain range might be the result of a geanticlinal movement, and the corresponding term "anticlinorium" was proposed for such an elevation. According to this view, the Appalachian range, when first formed at the close of Paleozoic time, was a typical synclinorium. In its reëlevation in Tertiary time, after the long Mesozoic cycle of

\* Deformation of Rocks.—II. An Analysis of Folds. *Journal of Geology*, vol. iv, pp. 312-353.

† This *Journal*, III, v, pp. 423-443.

erosion, the Appalachian range would be an example of an anticlinorium. The Sierra Nevada, when its rocks were crushed and folded at the close of the Jurassic, was a synclinorium. The broad uplift in Tertiary time of the broken arch whose abutments remain in the Sierra Nevada and the Wasatch, was an example of an anticlinorium.

The two words, as thus used by Professor Dana, seem perfectly appropriate to the significations which he assigned to them, and they seem to me to be still desirable terms in their original sense. Even those who do not accept Professor Dana's theoretical views in regard to the dynamics of mountain-making, must recognize the two types of mountain structure, as corresponding to two different processes of formation. The same distinction between the two types of mountain ranges has been recognized by Professor Le Conte,\* but the designations which he proposes for them seem far less elegant and appropriate than those proposed by Professor Dana in the article in question. The word "synclinorium" is used by Professor Dana in the last edition of his *Manual of Geology*† in precisely the same sense in which it was proposed in 1873.

The nomenclature proposed by Professor Van Hise is therefore objectionable, as involving a transfer of words which are still desirable in their original sense to an entirely different meaning. Moreover, the derivation of these words from the Greek *ōpos* which made them etymologically so elegantly appropriate in Dana's original use, seems to have no special appropriateness for the sense in which it is now proposed to use them. The masterly character of Professor Van Hise's article will undoubtedly give it a great influence over the thought and language of all students of Physical Geology. That it should lead them to the adoption of a nomenclature so objectionable, seems an event greatly to be deprecated.

W. N. B.

2. *Transactions of the Geological Society of South Africa*. Vol. I, March 1, 1896; II, pts. 1 and 2, February and March, 1896. Johannesburg. Edited by the Secretary, DAVID DRAPER, F.G.S.—Some of the papers, given in these transactions, the publication of which has been recently commenced, are as follows: The primary system of South Africa with special reference to the conglomerate beds of the Witwatersrand by David Draper; on the economic importance of the Murchison Range by C. Wilson-Moore; on Kimberley and its diamonds by W. Guybon Atherstone.

3. *The Rubies of Burma*.—In the January number of this Journal (p. 64) extensive quotations are given from the abstract of a most interesting paper by C. BARRINGTON BROWN and J. W. JUDD on the rubies of Burma and the associated minerals, their mode of occurrence, origin and metamorphoses. Those interested will be glad to learn that the full memoir has now been published in vol. clxxxvii, pp. 151-228 of the *Philosophical Transactions*.

\* *Elements of Geology*, Third Edition, pp. 264-266.

† *Manual of Geology*, Fourth Edition, p. 380.

## OBITUARY.

SIR JOSEPH PRESTWICH, D.C.L., F.R.S.,\* the most eminent of British geologists, has just passed away, and those who last Saturday stood around his grave amid the chalk hills of his pleasant country home at Shoreham, near Sevenoaks, felt that they were paying a last tribute to a veteran who had outlived all the associates of his prime, who had completed all his earthly tasks, and had gone to rest full of honors, and revered by all who knew him.

Joseph Prestwich was born in 1812 at Clapham, and after passing through elementary schools in London and in Paris, he proceeded to the famous grammar school of Dr. Valpy at Reading, and completed his education at University College in Gower street. At this college his thoughts were directed to science by the lectures of Edward Turner on chemistry and of Dionysius Lardner on natural philosophy. Turner, moreover, introduced the subjects of geology and mineralogy into his course, and thereby Prestwich gained those first lessons which aroused his interest and led him by force of circumstances to devote his leisure to geological studies. Had he been free to take up a profession he might, indeed, have given his special attention to chemistry. He was, however, destined to enter into commercial life, and until he was sixty years of age he was busily engaged in the city as a wine merchant. Assiduous and successful as a man of business, he yet contrived, from his earliest years in the office, to give great attention to geology, and he devoted all the leisure he could command to this subject, first of all as a means of relaxation, and finally because his interests were centered in the study. In early years his business-journeys enabled him to see and learn much about the general geology of England and Scotland; and when still a youth he spent his holidays during two successive years in studying the district of Coalbrook Dale in Shropshire, in mapping the various strata exposed at the surface from the Silurian rocks to the New Red Sandstone and Drifts, in marking the lines of fault, in noting in detail the character of the Coal Measures, and in gathering together the fossils from the several formations. The masterly memoir which he wrote on this area was communicated to the Geological Society of London in two portions in 1834 and 1836, being completed when the author was but twenty-four years of age. Meanwhile he had paid a visit to the north of Scotland, and had given some account of the ichthyolites of Gamrie in Banffshire, a task which he undertook at the suggestion of Sir Roderick (then Mr.) Murchison. This was his first paper published in the *Transactions* of the Geological Society, of which he had been elected a Fellow in 1833.

Later on he came to devote his special attention to the Eocene formations in the neighborhood of London, and in course of time he thoroughly investigated the entire area of the London Basin.

\* This notice is quoted from *Nature* of July 2d.



In particular he defined and named the Thanet Sands and the Woolwich and Reading Beds; and he studied the sequence of organic remains in the London clay, and the subdivisions of the Bagshot series. In these researches he paid especial attention to the lithological changes of the strata and to their fossils, so that he could picture the physical conditions under which the several formations were deposited. He extended his observations into the Hampshire Basin, and showed that the Bognor beds formed part of the London clay, and eventually he proceeded into France and Belgium to correlate the subdivisions there made with those he had established in this country. This great work among the Eocene strata occupied much of his time for nearly twenty years, and it served to fully establish his reputation not only as a keen and accurate observer, but as a most philosophical geologist. Another great achievement soon awaited Prestwich, and that was the investigation of the valley gravels supposed to contain the works of man in association with extinct mammalia. Boucher de Perthes had in 1847 announced such discoveries in the Somme Valley, but they had received little attention. The somewhat similar discoveries in Kent's Cavern, by MacEnery, had likewise been neglected. Attention was, however, forcibly directed to the subject by the discoveries made in Brixham Cave in 1858, and Dr. Falconer then induced Prestwich to examine the evidence brought forward in the valley of the Somme. The results of these researches, which were carried on in conjunction with Sir John Evans, and which were followed by a study of the English evidence at Hoxne, in Suffolk, in the Ouse Valley, and elsewhere, are well known. The contemporaneity of man with the Mammoth and other Pleistocene mammalia was fully established, and the antiquity of man came to be the most absorbing topic of the day. That vexed question still remains a matter under discussion, although Prestwich, in some of his later articles, has sought rather to reduce than to extend the time-limits of man's existence.

Subjects of practical importance from time to time engaged his attention. In 1851 he published "A Geological Inquiry respecting the Water-Bearing Strata of the country around London," a work which at once became the standard authority on the subject, and has lately been reissued with appendices. The author took a prominent part on the Royal Commission on Metropolitan Water Supply in 1867, and his services were again in request on the Royal Coal Commission, to the reports of which, published in 1871, he contributed accounts of the Bristol and Somerset Coal-field, and of the probable extent of Coal Measures beneath the Secondary rocks of the south and south-east of England. Agreeing generally with the conclusions of his friend Godwin-Austen, he was led to infer that concealed coal-fields might extend from Somersetshire eastwards to the neighborhood of Folkestone. Subsequent explorations at Dover have shown the correctness of these theoretical views.

Prestwich was elected a Fellow of the Royal Society in 1853, and was appointed a Vice-President in 1870. In that same year he was chosen President of the Geological Society, and in the course of his two addresses he dealt with the subjects of deep-sea researches and water-supply.

His attention had been given at various intervals to the later Tertiary deposits, and in 1871 his three great papers on the structure of the Crag-beds of Suffolk and Norfolk were published by the Geological Society. So much had been written by others on these very fossiliferous strata, that the author had not scope for so much originality as was the case with his Eocene researches. These later papers were, however, characterized by the same exhaustive treatment of the subject, in the record of many sections, and in the enumeration of the organic remains. His memoirs on the Pliocene or Crag formations were eventually followed by a series of articles dealing with more recent deposits. In the meanwhile Prestwich, who had retired from business in 1872, was offered the chair of Geology at Oxford, vacant through the death in 1874 of John Phillips. It came rather as a surprise to his friends that a man who had achieved such distinction and had earned repose should again go into harness. A young and ardent teacher would, however, at that time have been out of place, and, as events proved, no one better than Prestwich could have been selected to fill the post with such advantage to the University.

One result of his labors in Oxford was his large and handsomely illustrated work, in two volumes, entitled "Geology Chemical, Physical, and Stratigraphical"—a work in which he opposed the strictly uniformitarian teachings of some geologists, and urged that, though the agents were similar in kind in past ages, they were not similar in degree to those of the present day. Retiring from Oxford in 1888, Prestwich again surprised his many friends by his renewed activity. Paper after paper issued from his pen, dealing with the most difficult problems connected with the later superficial deposits—notably his memoir read before the Royal Society on the "Evidences of a Submergence of Western Europe and of the Mediterranean Coasts at the close of the Glacial or so-called Post-Glacial Period." He dealt also with the rudely-made plateau flint-implements of the Chalk Downs, many of them found near his Kentish home. Although individually they would not attract much notice, he maintained that these rudely-chipped flints bore traces of human workmanship, and collectively showed evidence of a peculiar type of earlier date than the ordinary Palæolithic implements.

These later writings of Prestwich have initiated many new lines of inquiry, even if they have failed to carry conviction to all his readers.

The last honor bestowed upon him, in the early part of this year, was that of knighthood, which he was unable to accept in person from Her Majesty owing to his feeble health. He died on June 23, at his home, Darent Hulme, near Shoreham. H. B. W.

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THE

# AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

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ART. XXI.—*On the regular or specular reflection of the Röntgen Rays from polished metallic surfaces*; by Prof. O. N. Rood of Columbia University.

THE source of the electricity in all the experiments detailed below was an ordinary induction coil made by Ruhmkorff: its length was 30 centimeters, its diameter 13·5. When the coil was in action a current of 4·8 amperes traversed it, and furnished a spark 90<sup>mm</sup> in length. In none of the experiments described in this paper did the discharge tubes heat sensibly. The tube employed in the earlier experiments had a diameter of 47<sup>mm</sup>, and contained a small calcined shell, which when acted on by the cathode rays, furnished X-rays quite abundantly from an area about 4<sup>mm</sup> square, and in smaller amounts from other portions of the shell and from the walls of the tube, as was proved by the aid of pin-hole photographs.

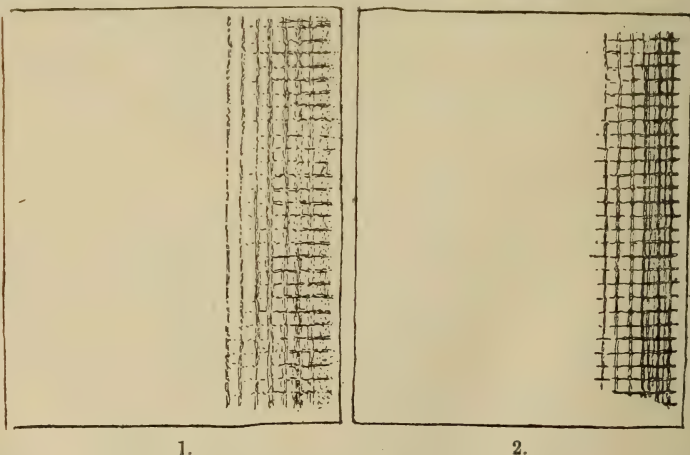
## 1. *Experiment with platinum foil, unmounted.*

The first decided indication of regular or specular reflection of the X-rays was obtained on March 13th, after an exposure of ten hours, a sheet of platinum foil 17·8 centimeters square being employed as the reflecting surface; the total distance from the walls of the vertical discharge tube to the plate-holder was 165<sup>mm</sup>. A short account of the result obtained was published in *Science*, on March 27th, 1896.

In this experiment the sensitive plate was shielded by a draw-slide that proved impervious to bright sunlight during an exposure of seven hours: in addition to this protection from ordinary light, it was completely covered by a plate of aluminium having a thickness of 0·17<sup>mm</sup>, and the central por-

tion of this plate was again covered by a horizontal strip of the same material, 25<sup>mm</sup> broad. Over this a netting of iron wire was fastened, the distance of the wires apart being 3·1<sup>mm</sup>, their thickness 0·54<sup>mm</sup>. This netting was destined to furnish the image or shadow-picture. I may remark in passing, that nettings like this, or coarser, are very useful in experiments on the X-rays, as they furnish accurate information as to uniformity of illumination, single or double sources of the rays, and also with regard to the relative transparency of objects placed on or in front of the plate-holder. It is hardly necessary to add that in the experiment with the platinum foil the plate-holder was protected by sheet lead from all direct emanations of the discharge tube. The angle of incidence was made as near 45° as could be accomplished with a divergent beam.

After the impression due to the reflected X-rays had been obtained, the sensitive plate was removed from the holder, also the shields of aluminium and the draw-slide, the wire netting alone being allowed to remain. The plate-holder, being then provided with a fresh sensitive plate, was replaced exactly in its original position, and exposed in the dark to a single discharge of the tube, the ordinary light of which was reflected to the naked plate by the foil. The image on the comparison plate thus obtained was of course due entirely to ordinary light that had been regularly reflected from the platinum, and the deformations of this image served to answer the question as to whether the X-rays also had undergone regular or specular reflection or only diffused reflection, or a mixture of both.



The accompanying woodcuts, figures 1 and 2, will serve to give some idea of the images obtained in the two cases. It will be noticed in figure 2, the picture obtained by ordi-

nary light, that the shadows of the vertical wires on the right hand are doubled; the corresponding lines of the X-ray picture are blurred and indistinct; again, in the picture taken by ordinary light the horizontal lines are distinct, which is also the case with the X-ray picture; in fact when the original negatives were examined, there was found to be a marked correspondence between the two, which "pointed," as I remarked in my article in *Science*, "strongly to the conclusion that in the act of reflection from a metallic surface the Röntgen rays behave like ordinary light." This negative contained evidence that some diffused X-rays had also reached the sensitive plate, for the image on it was as a general thing not as sharp as if it had been produced entirely by regularly reflected rays. Also an image of two vertical wires was produced outside of the space that could be reached by regularly reflected X-rays. This negative was too weak to furnish prints showing all the details, but from a study of it the conclusion was reached that a surface of platinum foil reflected the X-rays in the same general manner in which it reflected ordinary light, but that the percentage of the scattered X-rays was considerably larger than in the case of ordinary light, or in other words, that the platinum surface acted in connection with the X-rays as though it were imperfectly polished, a result that had been predicted by Dr. W. Gibbs.

Photographic experiments were also made to ascertain what percentage of the X-rays underwent reflection. Plates from the same box, protected in the same way, were placed at the same distance from the discharge tube, without the intervention of a mirror, and the time of exposure was diminished, till with similar development a similar image was obtained. The result of this determination was, that platinum foil at an angle of  $45^\circ$  reflected  $\frac{1}{240}$ th part of the incident X-rays.

#### *Experiments with mirrors of speculum metal and platinum.*

In order still further to study this matter and to extend the investigation to a second reflecting substance, on May 9th I employed a mirror made of speculum metal, its dimensions being  $64^{\text{mm}}$  by  $120^{\text{mm}}$ . This mirror was flat, but not particularly well polished. The shell tube was again used, and matters were so arranged that only one-half of the sensitive plate could be reached by regularly reflected ordinary light, or by regularly reflected X-rays. A coarser netting was employed, the distance from wire to wire being  $6.46^{\text{mm}}$ ; the diameter of the wire was  $0.8^{\text{mm}}$ . The same draw-slide was used to protect the plate; near its top it was covered by aluminium foil with a thickness of  $0.023^{\text{mm}}$ ; at the bottom it was crossed by a strip of aluminium plate having a thickness of



0.264<sup>mm</sup>. The angle as before was 45°; the total distance from the discharge tube to the sensitive plate was 177<sup>mm</sup>. The exposure lasted fifty hours and a strong negative was obtained. Just as in the previous experiment, a comparison negative was taken in a dark room with the ordinary light furnished by the tube and reflected from the mirror, the plate as before being naked and covered only by the netting. The exposure in this case lasted two minutes, though subsequent experiments showed that thirty seconds would have answered. Although the speculum mirror sent regularly reflected ordinary light to only one-half of the naked plate, yet the ordinary light diffused from its surface acted on the whole of the plate and gave a strong negative, which of course was much denser in that half of the plate reached by the regularly reflected rays.

It having thus been proved that the speculum mirror sent a portion of diffused ordinary light to the half of the plate not reached by regularly reflected light, it was to be expected that the same result would follow in the case of the plate exposed to the X-rays. This was found to be the case, but the difference in the densities of the two halves of the negative was less well marked. In the case of the X-ray negative, the vertical lines were somewhat blurred and broadened, owing to the action of the diffused rays, but in most portions of the plate the horizontal lines were sharp and not sensibly broader than the wires of the netting. This fact is difficult to account for on the supposition that the speculum mirror sent to the plate only diffused X-rays, as will be seen by what immediately follows. In order to ascertain what kind of an image diffused ordinary light, unmixed with regularly reflected light, would furnish, the face of the mirror was neatly covered with white paper which had been chalked to remove the last trace of its glaze. Negatives were taken in the same manner as that employed with the comparison plates above mentioned, the exposures being one, ten and thirty seconds. The three agreed in their details, but their appearance was totally different from that of the X-ray negative, the horizontal lines in particular being 5<sup>mm</sup> in breadth, instead of about 0.8<sup>mm</sup>, as was the case with the X-ray negative.

*Experiment with a platinum mirror.*—A piece of platinum foil was now cut of the same shape and size as the speculum mirror, and put in the position previously occupied by the latter. The platinum was cemented on a plate of glass having a plane surface, pains being taken to make the platinum lie as flat as possible. Its polish was not bad, but in spite of all efforts it was impossible to remove its small but visible irregularities of surface. As was to be expected, when used as a looking glass it furnished an image which was not distorted,

but hazy. The reflection experiment with X-rays above described was now repeated with its aid, the exposure as before being fifty hours. The result obtained was in general the same as before, with the important difference that the vertical lines were decidedly more blurred, and the sharp horizontal lines produced by the speculum metal rarely made their appearance. If flat metallic surfaces reflect only diffused X-rays, it is impossible to explain the marked differences exhibited by the negatives obtained from these two mirrors, which differed only in perfection of surface. It may be remarked in passing, that although no special attempt was made to measure the relative amount of the X-rays reflected by the two metals, yet the negative due to the platinum appeared slightly more dense, indicating a somewhat superior reflecting power.

*Experiment with a cylindrical mirror.*

While it would seem nearly impossible to explain the results above given, except on the assumption that X-rays reflected from flat polished metallic surfaces consist of regularly reflected rays mingled with others that have undergone diffuse reflection, yet it was decided to try another experiment that would be even more conclusive, and at the same time furnish at least a rough measure of the relative amounts of the two sets of rays. An ordinary pear-shaped Crookes tube was used, the hemispherical end of the tube opposite the cathode being the source of the X-rays. Its diameter was 90<sup>mm</sup>, the fluorescent portion having a diameter of about 83<sup>mm</sup>; hence the source of the X-rays was a rather large surface. The rays fell at an angle of 45° on a rectangular concave cylindrical mirror, its dimensions being 102<sup>mm</sup> by 170<sup>mm</sup>. The distance from the tube to the center of the mirror was 152<sup>mm</sup>; from the center of the mirror to that of the plate-holder it was 165<sup>mm</sup>. The surface of the cylindrical mirror was made of lead-foil faced with a thin coating of tin; the polish was brilliant.\* The specific gravity of the foil was 10.87. This foil was cemented on a sheet of mica, which was then bent so as to form a concave cylindrical mirror, the radius of its central portion being 255<sup>mm</sup>; those of the external portions were somewhat greater. The mirror was placed so that the axis of the cylinder was vertical. Owing to the arrangement and the size of source of illumination, the beam of ordinary light reflected from the mirror to the plate-holder was somewhat divergent, but less so than would have been the case with a flat mirror. The lead-foil mirror of course had certain deformations, generally verti-

\*This a commercial article in the United States, and is known simply as "tin foil."

cal, but they were of no consequence in the experiments that followed. In a perfectly darkened room the ordinary whitish green light from the end of the tube was reflected from the cylindrical mirror towards the plate-holder faced with white paper, and the shadows cast by vertical and horizontal wires were studied. This beam of light had certain characteristics impressed on it by the act of regular or specular reflection from the cylindrical mirror, and it was found that the shadows of the *vertical* wires of a netting held at a distance of a few millimeters from the plate-holder were blurred and doubled, while the shadows of the *horizontal* wires remained perfectly sharp and single. In order to study these shadows with a stronger illumination, the Crookes tube was removed, and its luminous end replaced by a circular transparent screen 83<sup>mm</sup> in diameter, illuminated from behind with a gas-flame, but no new facts were developed.

The apparatus being properly arranged, the tube and mirror were cemented fast to their supports, and the plate-holder was provided with cemented guides, so that after removal it could be returned to its original position. In the first experiment the sensitive plate was shielded only with the draw-slide that had proved impervious to an exposure of seven hours of sunlight; on it was fastened a coarse wire netting, the average distance between the wires being 12.3<sup>mm</sup>; the thickness of the wire was 1.34<sup>mm</sup>. This plate was exposed for forty-six hours to the reflected X-rays, and furnished a fine negative. Lest it should be urged that it was partly due to ordinary ultra violet light, a second plate was exposed for ninety hours, the strips of aluminium foil and aluminium plate above mentioned being used. These were fastened on the plate-holder diagonally, so as to interfere as little as possible with the image. There was no difference between the 46-hour and the 90-hour negatives, except in the matter of density; the foil left no trace of its presence, but the portions under the aluminium plate were a little less strong.

As was expected, the vertical lines in both negatives were broadened and blurred, their diffused image in some cases extending half-way across the open squares, while on the other hand the horizontal lines were sharply defined and scarcely broader than the wires that produced them. The mirror was now covered up with chalked paper neatly fitted to its surface, and a negative taken with an exposure of one minute, the whitish green light from the end of the Crookes tube being employed as the source of illumination. Its appearance was totally different from that obtained by the use of the X-rays, the shadows of both horizontal and vertical wires having a tolerably uniform breadth of about 6<sup>mm</sup>. This negative, taken



by diffused ordinary light, had a certain character of its own, in the disposition for example of its horizontal bands, and a study of the 90-hour negative convinced me that it also contained decided evidence of the presence of similar diffused horizontal bands, and that in point of fact upon the same plate were *two* impressions superimposed, one due to regularly reflected X-rays, the other to the same rays in a diffused condition.

It now remained to attempt to make an estimate of the relative amounts of the regularly reflected and diffused X-rays in the case of the 90-hour negative. This I undertook to accomplish by mixing together ordinary diffused with ordinary specularly reflected light, till the mixture should furnish a negative corresponding in appearance with that obtained with the X-rays. It was first ascertained by an ordinary photometric determination that the cylindrical mirror sent to the plate-holder a certain amount of light, and that when this mirror was covered up by unglazed white paper, the plate-holder received only one-quarter of this amount, the original source in both cases being the end of the Crookes tube. Consequently, when the cylindrical mirror was covered up with a sheet of this paper from which one-half of the surface had been removed, chess-board fashion, the sensitive plate would be acted on by four parts of regularly reflected ordinary light, and by one part of light that was equally diffused in all directions, that is, it would receive 80 per cent. of regularly reflected ordinary light, and 20 per cent. of diffused. A negative taken after this fashion, when compared with the 90-hour X-ray negative, was found to have received too small an amount of diffused light. The mirror was then covered by a different sheet of the same paper, perforated after the same general fashion, but furnishing to the sensitive plate a mixture of 36 per cent. of regularly reflected and 64 per cent. of diffused light. This second negative showed that too much diffused light had been employed, and that the most appropriate mixture would not be far from equal parts of the two kinds of light. Consequently it was concluded that, according to this imitative experiment, the 90-hour negative had been acted upon by approximately equal parts of regularly reflected and diffused X-rays. The experiment was not pushed farther, as a study of these negatives convinced me that *no* mixture of regularly reflected and of equally diffused light would furnish more than a coarse imitation of the X-ray negative, there being details on the latter which no such mixture could reproduce. The explanation of this lies, as I take it, in the fact that polished metallic surfaces do not furnish a mixture of regularly reflected and of *equally* diffused X-rays; they appear, according to my observations, to furnish, at an angle of  $45^\circ$ , a certain

amount of regularly reflected X-rays, along with a certain quantity of X-rays that are not equally scattered in all directions, but that stray from their more orderly companions only to a moderate extent; that is, the diffusion has the character that obtains with ordinary light reflected from imperfectly polished mirrors. It would appear then, according to these experiments, that metallic surfaces which are highly polished for ordinary light are only imperfectly polished for the X-rays, and it may be added that all the experiments detailed in this paper are in harmony with the idea that the X-rays consist of transverse waves like those that constitute ordinary light, differing from them only in being much shorter.

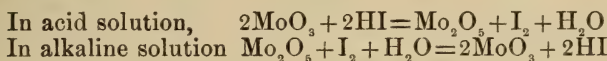
In the earlier experiments I was much annoyed by the presence on the plates of systems of variously curved lines, which either obscured or blotted out the photographic impression. These curves had a breadth of a few millimeters and were never twice alike in shape. They always made their appearance in the preliminary experiments on reflection, and sometimes even when the X-rays were allowed to fall directly on the plate-holder without the intervention of a mirror. They appeared to be due to ordinary static induction, and were finally abolished by replacing the sheet-iron slide that contained the plate by one made of wood, and insulating the plate-holder by supporting plates of glass. The large lead screen between the discharge tube and the plate-holder was also carefully grounded. With these precautions the electrical markings became very faint, and indeed quite imperceptible except with short exposures that furnished very faint negatives.

New York, June 17, 1896

ART. XXII.—*An Iodometric Method for the Determination of Phosphorus in Iron*; by CHARLOTTE FAIRBANKS.

[Contributions from the Kent Chemical Laboratory of Yale University, LIV.]

A RECENT paper from this laboratory\* showed that molybdic acid was reduced by hydriodic acid to the condition of oxidation represented by the symbol  $\text{Mo}_2\text{O}_5$  in acid solution, while in an alkaline solution the reduced product was reoxidized by standard iodine.



These reactions obviously present the possibility of developing a method for the determination of phosphorus in the phospho-molybdates.

The very careful work of Messrs. Blair and Whitfield† shows conclusively that the ammonium phospho-molybdate, precipitated under the conditions ordinarily prescribed for the determination of phosphorus in iron or iron ores, is of definite constitution. They find that  $24\text{MoO}_3$ ,  $\text{P}_2\text{O}_5$ ,  $3(\text{NH}_4)_2\text{O}$ ,  $2\text{H}_2\text{O}$  expresses the composition of this phospho-molybdate, which therefore contains 1.794 parts of phosphorus to every 100 parts of molybdic anhydride.

This being the case, it is plain that if advantage can be taken of the fact that the amount of iodine necessary to reoxidize reduced molybdic acid is large, as well as of the fact that the amount of molybdic acid compared to the phosphorus contained in the phospho-molybdate is also large, a method of great theoretical accuracy should result.

I have experimented with a process which consists essentially in treating the ammonium phospho-molybdate, produced by the accepted methods of iron analysis, with potassium iodide in the presence of strong hydrochloric acid and under carefully regulated conditions; in neutralizing the residue thus obtained by acid sodium carbonate; and in reoxidizing the reduced molybdenum compound to the condition of molybdic acid by titration with iodine.

The directions prescribed by Messrs. Blair and Whitfield for making the ammonium molybdate solution were followed: 100 grams of molybdic anhydride are intimately mixed with  $400^\circ\text{C}$  of distilled water and  $80^\circ\text{C}$  of strong ammonia, and after filtering, this liquid is poured into a mixture of  $300^\circ\text{C}$  of nitric acid

\* Gooch and Fairbanks, this Journal, vol. ii, p. 156.

† Jour. Am. Chem. Soc., vol. xvii (1895).



(1.42 sp. gr.) and 700° of water. This solution, it is said, practically remains unaltered for months; but it is much safer to filter each day the portion to be used.

In order to obtain a standard solution of phosphorus, 1.2 grams of microcosmic salt were dissolved in one litre of water and 50° of this solution were evaporated, and the residue ignited and weighed as sodium metaphosphate.

Iron free from phosphorus, for admixture with known amounts of phosphorus in the test experiments, was prepared by igniting ferrous oxalate. The oxalate was precipitated by oxalic acid from ferrous sulphate dissolved in warm water. The precipitate was then thoroughly washed with cold water, dried and ignited.

The ferric oxide thus obtained was dissolved in hydrochloric acid, evaporated to dryness, and dried on a hot plate. The ferric chloride was treated with nitric acid and the solution evaporated twice. In this way all but a trace of the chloride was destroyed,

Since in the ordinary determination of phosphorus in iron, potassium permanganate is added, as Dr. Drown says,\* to insure the complete oxidation of the phosphorus to the orthophosphoric acid, it seemed best to make sure that this treatment was not detrimental in the process to follow. Enough permanganate was therefore added in my experiments to distinctly color the already boiling solution of ferric nitrate, and then a little tartaric acid was used to clear the solution.

As too much free acid prevents the full precipitation of the ammonium phospho-molybdate, the ferric nitrate solution was treated with ammonia until a precipitate or the ruby wine color appeared. Then dilute nitric acid was added until the color of the solution was a clear amber. Generally four or five grams of ferric oxide were used in each determination.

The ferric nitrate and phosphorus solutions, in volume not less than 150° nor more than 300°, were drawn into an ordinary 500° flask. The flask was heated on the steam bath to just 85° C.—very carefully, since at higher temperatures there is danger of precipitating molybdic acid—and immediately 40° of the filtered ammonium molybdate solution were so added as to wash down the thermometer and the sides of the flask. The flask was corked, wrapped in a towel, and shaken for five minutes. The contents were filtered at once on an asbestos felt, and the precipitate washed three or four times, first with a 10 per cent solution of nitric acid, and then with a 1 per cent solution of potassium nitrate.

If the nitric acid and potassium nitrate solutions wash the

\* Trans. Am. Inst. of Min. Eng., vol. xviii, p. 93.

flask and cork each time, it will do no harm if some of the precipitate still adheres to the sides of the flask; for the flask, cork and crucible are all finally washed with ammonia. The asbestos felt was transferred to a 100<sup>cc</sup> flask or narrow based Erlenmeyer. The precipitation flask and cork were thoroughly washed with a mixture of 5<sup>cc</sup> of ammonia and 10<sup>cc</sup> of water, and the washings were allowed to rinse the sides of the perforated crucible—standing on a small funnel—and so to run into the 100<sup>cc</sup> flask. Twenty-five cubic centimeters of strong hydrochloric acid were added and, where the phosphorus does not exceed .0060 grm., 0.5 grm. of potassium iodide; but, where more than .0060 grm. of phosphorus is present, a little more potassium iodide is theoretically and practically needed. Experience has shown that the iodide present should not exceed the amount theoretically necessary by more than a half gram.

The liquid was boiled down from a total volume of 40<sup>cc</sup> to just 25<sup>cc</sup>, a volume easily marked by two strips of paper pasted on opposite sides of the flask. If the solution is boiled farther, the molybdic acid is likely to be reduced beyond the degree of oxidation indicated by the symbol  $\text{Mo}_2\text{O}_5$ . The residue was neutralized with acid sodium carbonate, according to one or the other of the methods described below, and treated with an excess of standard iodine.

For a trap to prevent loss during boiling, a two-bulbed drying tube was cut off an inch and a half below the largest bulb and this end fitted loosely into the neck of the flask, as shown in the accompanying figure. The addition of two or three little pieces of pumice stone, previously boiled in hydrochloric acid, insures quiet boiling.



While still acid the reduced solution is not appreciably reoxidized in the air, but when once made alkaline it is very easily changed. Therefore great care must be taken either to have the iodine present before the solution is made alkaline; or else to stir up the solution as little as possible while adding the alkalis and to draw in the iodine solution immediately.

The safer method is to put the reduced solution, with one gram of tartaric acid, to prevent the precipitation of the molybdenum, and an excess of the iodine solution, amounting to at least 8<sup>cc</sup>, into a liter flask. This flask was fitted with a paraffined rubber stopper, carrying a funnel with a stop-cock for admitting slowly the acid sodium carbonate to effect neutralization, and a Will and Varrentrapp trap, filled with a solution of potassium iodide, to catch the iodine thrown off during the effervescence.

The more convenient way, and after a little practice a serviceable method for rapid work, is to put the solution and the tartaric acid in a bottle, to add enough sodium hydroxide to nearly neutralize the free acid, and then to make the solution distinctly alkaline with an excess of acid sodium carbonate, tipping the flask to one side to prevent loss during the effervescence. The iodine solution must be drawn in immediately or atmospheric oxidation will take place and the error of the process be great.

After either method of neutralization the iodine color in the solution should perceptibly fade within fifteen minutes; but for complete oxidation the corked bottle should be set aside, out of sunlight, for an hour and a half, and then the excess of the iodine titrated with a standard solution of arsenious acid.

Since there is a slight tendency on the part of the iodine, especially when the sodium hydroxide and the acid sodium carbonate are used for neutralization, to form a little iodate, it is wise to acidulate the solution in each case slightly with dilute hydrochloric acid after the titration with the arsenic solution, and then to determine by sodium thiosulphate the trace of iodine which has taken the form of iodate.

In the following table the absolute errors in terms of phosphorus are given; and the percentage errors, between the phosphorus taken and the phosphorus found, referred to 10 grams of material—the maximum amount of high grade iron or steel usually taken for analysis—are also added.

|      | Am't of P<br>taken. | Am't of P<br>found. | Error on P. | % Error of P. | Neutralized by            |
|------|---------------------|---------------------|-------------|---------------|---------------------------|
| I    | 0.002727            | 0.002778            | 0.000051 +  | 0.0005 % +    | NaHCO <sub>3</sub>        |
| II   | 0.001812            | 0.001743            | 0.000069 -  | 0.0007 % -    | NaOH + NaHCO <sub>3</sub> |
| III  | 0.000909            | 0.000914            | 0.000005 +  | 0.00005 % +   | NaOH + NaHCO <sub>3</sub> |
| IV   | 0.003508            | 0.003262            | 0.000246 -  | 0.002 % -     | NaOH + NaHCO <sub>3</sub> |
| V    | 0.005454            | 0.005417            | 0.000037 -  | 0.0003 % -    | NaHCO <sub>3</sub>        |
| VI   | 0.001818            | 0.001861            | 0.000043 +  | 0.0004 % +    | NaOH + NaHCO <sub>3</sub> |
| VII  | 0.003636            | 0.003716            | 0.000080 +  | 0.0008 % +    | NaHCO <sub>3</sub>        |
| VIII | 0.000909            | 0.000988            | 0.000079 +  | 0.0007 % +    | NaHCO <sub>3</sub>        |
| IX   | 0.000363            | 0.000289            | 0.000074 -  | 0.0007 % -    | NaOH + NaHCO <sub>3</sub> |
| X    | 0.008180            | 0.008179            | 0.000001 -  | 0.00001 % -   | NaHCO <sub>3</sub>        |

The error in IV is obviously high, and, in view of the results obtained in the former paper to which reference has been made, undoubtedly accidental; but the result is inserted in the series because no reason was apparent for excluding it.

In all of the experiments, with one exception, from four to five grams of pure iron oxide were introduced; in experiment IX the amount was 2.5 gm.

In the first nine experiments, 0.5 gm. of potassium iodide was used; in experiment X more was theoretically necessary and 0.75 gm. was added.



The foregoing table shows that satisfactory results in the determination of phosphorus in iron can be obtained by precipitating the ammonium phospho-molybdate according to the usual methods of iron analysis; then reducing the phospho-molybdate thus obtained with potassium iodide and hydrochloric acid; neutralizing the residue with acid sodium carbonate, and reoxidizing with standard iodine.

In conclusion, I wish to express my thanks to Professor Gooch for his help and friendly interest.

ART. XXIII.—*On the Reduction of Vanadic Acid by Hydriodic and Hydrobromic Acids, and the Volumetric Estimation of the same by titration in alkaline solution with Iodine*; by PHILIP E. BROWNING.

[Contributions from the Kent Chemical Laboratory of Yale University—LV.]

THE reduction of vanadic acid from the condition of the pentoxide to that of the tetroxide by the action of hydriodic and hydrobromic acids has been applied to the volumetric determination of vanadium. Holverscheit\* has shown that when a vanadate is treated with potassium bromide and strong hydrochloric acid, and the bromine liberated on boiling is passed into a solution of potassium iodide, the iodine set free and estimated shows the reduction to have gone to the condition of the tetroxide. This method is said to yield most satisfactory results.

Friedheim in a recent paper† gives the method favorable comment, and shows also by a carefully made series of experiments that the pentoxide may be reduced to the tetroxide by boiling with potassium iodide and sulphuric acid, and, further, that the reduction may be carried even to the condition of the trioxide by substituting for the sulphuric acid strong hydrochloric acid.

In both of the above mentioned methods the iodine liberated is conducted into a solution of potassium iodide and estimated in the usual manner.

In a former paper‡ I have shown that vanadic acid may be determined conveniently and rapidly by reducing it to the tetroxide by the action of tartaric acid and estimating it in the residue by direct oxidation with standard iodine after having cooled the solution and having made it alkaline with a bicarbonate. The possibility of applying this method of oxidation

\* Dissertation, Berlin, 1890.

† Berichte d. d. chem. Gesell., xxviii, 2067 (1895).

‡ Zeitschr. f. anorgan. Chem., vii, 158 (1894).

to the residue after the reduction with hydrobromic and hydriodic acids led to the series of experiments which it is the purpose of this paper to describe. The advantages of the treatment of the residue are obvious and the general method has been applied in a number of methods previously developed in this laboratory. In the first place the complicated apparatus necessary for the distillation and collection of the bromine or iodine is unnecessary, an ordinary boiling flask or Erlenmeyer beaker being sufficient. In case the distillation process is preferred, the residue may be treated by the method to be described as a control and the results by both processes allowed to check one another.

For the work to be described solutions of ammonium vanadate were made and standardized by evaporating measured and weighed portions in a platinum crucible to dryness, and igniting in the presence of a drop of nitric acid.

The reduction with hydriodic acid was first tried; the method in general was as follows: Measured and weighed portions of the vanadate solution were placed in the Erlenmeyer beakers, the amounts of potassium iodide indicated in the tables added from a ten per cent solution and finally 10<sup>cm</sup><sup>3</sup> of a mixture of sulphuric acid and water in equal parts. The contents of the flask was then boiled until the fumes of iodine were no longer visible and the escaping steam gave no indication of free iodine with red litmus paper.\* This point was reached when the volume of the liquid reached about 35<sup>cm</sup><sup>3</sup>. If large amounts of potassium iodide were used the resulting color was green, owing to the presence of iodine, dissolved in hydriodic acid, with the blue tetroxide of vanadium; if smaller amounts of the iodide were used the resulting color was blue. The flasks were then removed from the flame and the contents nearly neutralized by the addition of a solution of potassium or sodium hydroxide,† cooled, and the neutralization completed with potassium bicarbonate in excess; care being taken to add a few drops of a tartaric acid solution to prevent the precipitation of the tetroxide. To the cooled solution a solution of iodine in potassium iodide was added in slight excess. This point can be quite easily determined, as the iodine is bleached rapidly if the solution is allowed to mix thoroughly as it is drawn from the burette into the flask. After the addition of a distinct excess of the iodine the flask should be closed with a cork coated with paraffin and allowed to stand about one-half hour. It will be noticed that

\* Gooch and Mar, this Journal, xxxix, p. 300.

† The potassium or sodium hydroxide for this work must be free from alcohol, as the solution is allowed to stand with iodine after neutralization. It was prepared by mixing potassium or sodium carbonate in proper proportions with calcium oxide and filtering off the calcium carbonate.

at the end of about fifteen minutes the iodine has ceased to bleach, showing the oxidation to be complete. I have generally allowed the flasks to stand a few minutes longer to be sure of a complete oxidation. The excess of iodine is then destroyed by standard arsenious acid solution, against which the iodine has been previously standardized, starch added and the color brought back with a few drops of iodine. The amount of arsenious acid solution used for the bleaching of the iodine, in terms of iodine subtracted from the whole amount of iodine used, gives the amount of iodine necessary to oxidize the vanadium from the condition of tetroxide to that of pentoxide. The results follow in the table.

|      | V <sub>2</sub> O <sub>5</sub> taken.<br>gram. | V <sub>2</sub> O <sub>5</sub> found.<br>gram. | Error.<br>gram. | Amount KI.<br>gram. | Amount<br>H <sub>2</sub> SO <sub>4</sub> (1 <sup>-1</sup> )<br>cm <sup>3</sup> . |
|------|---|---|-----------------|---------------------|--|
| (1)  | 0.1699  | 0.1690  | 0.0009—         | 1                   | 10   |
| (2)  | 0.1704  | 0.1699  | 0.0005—         | 1                   | 10   |
| (3)  | 0.1706  | 0.1700  | 0.0006—         | 1                   | 10   |
| (4)  | 0.1702  | 0.1692  | 0.0010—         | 1                   | 10   |
| (5)  | 0.3613  | 0.3620  | 0.0007+         | 1.5                 | 10   |
| (6)  | 0.1805  | 0.1803  | 0.0002—         | 1                   | 10   |
| (7)  | 0.3614  | 0.3620  | 0.0006+         | 1.5                 | 10   |
| (8)  | 0.1811  | 0.1814  | 0.0003+         | 1                   | 10   |
| (9)  | 0.1807  | 0.1815  | 0.0008+         | 1                   | 10   |
| (10) | 0.3613  | 0.3620  | 0.0007+         | 1.5                 | 10   |
| (11) | 0.3679  | 0.3674  | 0.0005—         | 1.5                 | 10   |
| (12) | 0.3612  | 0.3608  | 0.0004—         | 1.5                 | 10   |
| (13) | 0.2893  | 0.2907  | 0.0014—         | 1.5                 | 10   |
| (14) | 0.3456  | 0.3448  | 0.0008—         | 1.5                 | 10   |
| (15) | 0.3453  | 0.3448  | 0.0005—         | 1.5                 | 10   |
| (16) | 0.3907  | 0.3912  | 0.0005+         | 2                   | 10   |
| (17) | 0.3908  | 0.3898  | 0.0010—         | 1                   | 10   |
| (18) | 0.3906  | 0.3921  | 0.0015+         | 2                   | 10   |
| (19) | 0.3909  | 0.3912  | 0.0003+         | 1.5                 | 10   |

The results are on the whole satisfactory, the average error of all the determinations being less than 0.0002—. It will be noticed that large amounts of potassium iodide tend to give plus errors, probably due to the tendency of the hydriodic acid to hold iodine.

The action of the hydrobromic acid was tried in exactly the same manner. It was found that when the residual volume of the liquid in the flask reached 25<sup>cm</sup><sup>3</sup> the blue color appeared, and the absence of free bromine was proved by holding a paper moistened with potassium iodide in the steam. If the boiling is not carried to the point indicated, where the blue color appears, the results come low, showing incomplete reduction. The results follow in the table.



|      | V <sub>2</sub> O <sub>5</sub> taken.<br>gram. | V <sub>2</sub> O <sub>5</sub> found.<br>gram. | Error.<br>gram. | Amount KBr.<br>gram. | Amount<br>H <sub>2</sub> SO <sub>4</sub> <sup>(1-1)</sup><br>cm <sup>3</sup> . |
|------|---|---|-----------------|----------------------|--|
| (1)  | 0.1890  | 0.1876  | 0.0014—         | 1                    | 10   |
| (2)  | 0.1886  | 0.1886  | 0.0000±         | 2                    | 10   |
| (3)  | 0.1885  | 0.1882  | 0.0003—         | 1                    | 10   |
| (4)  | 0.1885  | 0.1886  | 0.0001+         | 1.5                  | 10   |
| (5)  | 0.1881  | 0.1873  | 0.0008—         | 1.5                  | 10   |
| (6)  | 0.1886  | 0.1882  | 0.0004—         | 2                    | 10   |
| (7)  | 0.3907  | 0.3894  | 0.0013—         | 2                    | 10   |
| (8)  | 0.3907  | 0.3903  | 0.0004—         | 2                    | 10   |
| (9)  | 0.3907  | 0.3894  | 0.0013—         | 2                    | 10   |
| (10) | 0.3909  | 0.3889  | 0.0020—         | 2                    | 10   |
| (11) | 0.3911  | 0.3903  | 0.0008—         | 1.5                  | 10   |
| (12) | 0.3902  | 0.3900  | 0.0002—         | 2.5                  | 10   |

Average error of series = 0.0007—.

May, 1896.

ART. XXIV.—*The Bearpaw Mountains of Montana. Second Paper, (Part II);*\* by WALTER HARVEY WEED and LOUIS V. PIRSSON.

THROUGHOUT the Bearpaw Mountains dikes of igneous rock are often seen, and in certain localities they form conspicuous features of the mountain slopes, weathering out as bold walls of rock; frequently, however, the ready weathering of a minette-like rock, of common occurrence in the mountains, makes the recognition of such dikes difficult, except where contact walls of hardened shale stand in relief, or the course of the dike is marked by an unusually luxuriant growth of grass.

About the Wind Butte intrusive stock the dikes possess a radial disposition, and may be seen extending across country for several miles. Elsewhere the observations were not complete enough to warrant the statement that the dikes radiate from igneous centers, though this seems to be the case about the stock exposed on upper Beaver Creek.

Most of the dikes observed were found cutting sedimentary beds which they have indurated and altered near the contact, but in a few instances the dikes are in the extrusive breccias, and at Beaver Creek a tinguaitite dike cuts the granular igneous rock of the stock.

\* Published by authority of the Director of the United States Geological Survey.

The rock types represented include syenite porphyry, "leucite" basalt (this rock also occurring as extrusive flows and breccias), tinguaites in considerable variety, and micaceous rocks that are probably to be classed as minettes. The first two types do not need especial mention. They were seen on Beaver Creek and in various other parts of the mountains.

The minette-like dikes were observed at many of the points visited; they occur in abundance about the Wind Butte stock and on Beaver Creek.

### *Tinguaitite Dikes.*

The tinguaites form the most striking and characteristic rock of the mountains. The term is used for those dense rocks, whether porphyritic or not, which are composed chiefly of alkali feldspars, and carry such large amounts of ægirite in the fine-grained groundmass that they have a pronounced greenish color, and megascopic habit that furnishes a useful characteristic for discrimination.\* These rocks form the most conspicuous feature of the drift both within and about the mountains, their bright green color, large white feldspar crystals, and the glassy polish which the surface assumes upon weathering, making them appear in striking contrast to the other rocks with their dark tones of color. These tinguaitic rocks are not, however, of as frequent occurrence as the widespread abundance of the drift would indicate, as the rock is very tough and resistant, and resists disintegrating agencies better than any other rock type of the mountains.

East of the Wind Creek stock the high ridges forming the divide between the People's Creek basin and the headwaters of Bean and Snake creeks show a swarm of tinguaitite dikes, forming walls which are conspicuous features of the grassy ridges and extending eastward to the main road.

*Tinguaitite porphyry.*—On the high ridge running east from Wind Butte, some twelve or more nearly parallel dikes of this rock were observed. The rock seldom forms continuous walls, though it is very hard, tough and resistant, rings sonorously under the hammer, and is broken with great difficulty. It is jointed, and breaks in large cubical blocks. The shales and sandstone beds are highly altered in the space between the dikes. A decomposed brownish feldspathic rock appears to be a frequent accompaniment. The dikes vary from a few feet to 12 feet in width. At the contact the rock is dense and without the large porphyritic crystals which are so conspicuous in the main mass of the dike,—a most important feature, as

\* This Journal, vol. 1, 1895, p. 399.

it shows that they were formed in place, as noted later, and *are not of intratelluric origin.*

In the hand specimen the rock has a strong green color of a grayish tint on fresh fracture, and has a pronounced spotted appearance, owing to the great number of large feldspar phenocrysts with which the dark groundmass is thickly crowded. These feldspar phenocrysts are of a very pale gray color or white, are usually quite idiomorphic, and generally show a short, thick tabular habit; in size they vary from 5 to 15<sup>mm</sup> in length by half that in breadth. They are often single, sometimes grouped; some are simple individuals, others are carlsbad twins. While usually more or less opaque, they are often clear, glassy, and of sanidine habit. They have excellent cleavages, that parallel to *c*(001) being very perfect.

The green groundmass examined with the lens is seen to be full of small glittering black augite prisms rarely more than 1<sup>mm</sup> long; these can be frequently seen lying in the feldspar phenocrysts. The base in which these lie cannot be resolved by the lens, but is evidently crystalline and of a dark green color with a dull, greasy luster. An occasional speck of yellow chalcopyrite and of a resinous brown mineral, which is thought to be titanite, completes the list of minerals which are megascopically visible.

Microscopically the minerals seen are *apatite*, *ægirite*, *augite*, *alkali feldspar*, *nephelite*, *cancrinite*, a little *sodalite*, and a doubtful fibrous *hornblende*.

The *pyroxenes* are very peculiar. They consist largely of *ægirite*-*augite* and *ægirite*; instead of *ægirite* forming an exterior mantle, as is usually the case where these two occur together, there are alternate zonal bands and patches of deep green material and paler yellowish green, as if the formation of the *ægirite* molecule had varied in amount from time to time. Another striking peculiarity of these augites consists in the fact that they generally contain interior cores of a perfectly colorless pyroxene-like mineral. In no case is there a gradual transition from the colorless core to the green *ægirite*; the line of juncture is perfectly sharp and well-defined. The cores also have jagged irregular outlines, and are not of one piece but consist of bundles of irregular strips, staves and kernels, which vary in their optical orientation, and around these colorless masses the deep green *ægirite* has grown, filling their interspaces and completing the crystal form. The mineral has a prismatic habit, two cleavages at nearly 90°; like pyroxene, both the refraction and birefraction are high. In the length section, which is also that of the compound pyroxene, the strips extinguish nearly parallel; in cross sections the extinction cuts the cleavages at an angle. The vertical axis is



the acute bisectrix and is  $c$ ; the angle of the optic axes is rather small,  $2E = 75^\circ - 80^\circ$  as nearly as could be measured with a micrometer ocular with movable thread; in this case the plane of the optic axes was  $15^\circ$  from one of the prismatic cleavages; the bisectrix was not exactly centered. What the exact nature of these pyroxene-like cores is, must be largely a matter of conjecture; the analysis and the calculated mineral composition derived from it seem to indicate clearly that they are a diopside-like product.

The large phenocrysts of *feldspar* are orthoclase or rather sanidine in some cases. They have an excellent cleavage parallel to  $c(001)$ , a less perfect one parallel to  $b(010)$ . The angle  $2E$  was measured about  $80^\circ$  with a micrometer ocular; the measurement is approximate, as the bisectrix was not perfectly centered. The extinction on  $c(001)$  appears rigidly parallel to the trace of  $b(010)$ ; on  $b(010)$  it is  $7^\circ$ . These were determined on cleavage fragments. In thin section it appears perfectly fresh, homogeneous and uniform. It contains quantities of ægirite microlites as inclusions, and it is noticeable that numbers of the feldspars have an interior wreath or shell of these ægirites, as if marking a definite period of renewed growth.

Another peculiarity is that the ægirite prisms of all sizes lying outside of these feldspars are all arranged parallel to the sides of the feldspar and form a sort of coating or mantle around them. They appear exactly as if, having been already present, the growing and expanding feldspars had pushed them along, exactly as a heap of scattered straws lying on a table would be arranged in parallel position if swept to one side by a broom. That this phenomenon is not due to fluidal movements of the molten rock is clearly shown by the fact that the ægirite prisms surround all the faces of the feldspar in this way, and by the further fact that the flattened tablets of feldspar themselves lie unoriented, scattered in all positions in the rock. It thus really appears that these large phenocrysts are of later origin than the greater number of the augites, though the latter are so much smaller, thus agreeing with the megascopical characters previously mentioned.

The *groundmass* is composed of the same minerals, with the addition of formless grains of fresh nephelite and an occasional one of sodalite and cancrinite. There is, indeed, no sharp line of division, and the size of the components grades from the largest to the smallest; the ægirite eventually sinks to extremely fine slender microlites; it occurs only in the form of slender prisms. In some cases the ægirites of largest size appear to be altered to a finely fibrous aggregate of a deep green color; whether this is still ægirite or a fine hornblende cannot be certainly told.

The chemical composition of this interesting rock is shown in the following analysis by Dr. H. N. Stokes, given in No. I.

|                                      | I.     | II.      | III.  | IV.   |
|--------------------------------------|--------|----------|-------|-------|
| SiO <sub>2</sub> .....               | 57.46  | 57.63    | 56.58 | 54.46 |
| Al <sub>2</sub> O <sub>3</sub> ..... | 15.40  | 17.53    | 19.89 | 19.96 |
| Fe <sub>2</sub> O <sub>3</sub> ..... | 4.87   | 3.46     | 3.18  | 2.34  |
| FeO .....                            | .87    | 1.18     | .56   | 3.33  |
| MgO .....                            | 1.37   | .22      | .13   | .61   |
| CaO .....                            | 2.59   | 1.35     | 1.10  | 2.12  |
| Na <sub>2</sub> O .....              | 5.48   | 5.80     | 10.72 | 8.68  |
| K <sub>2</sub> O .....               | 9.44   | 9.16     | 5.43  | 2.76  |
| H <sub>2</sub> O—110° .....          | .09    | 3.22     | 1.77  | 5.20  |
| H <sub>2</sub> O+110° .....          | .82    |          |       |       |
| TiO <sub>2</sub> .....               | .60    | .23      | ?     | trace |
| Cl .....                             | .20    | .08      | ?     | ?     |
| P <sub>2</sub> O <sub>5</sub> .....  | .21    | trace    | ?     | ?     |
| SO <sub>3</sub> .....                | .13    | ----     | ----  | ----  |
| CO <sub>2</sub> .....                | .13    | ----     | ----  | ----  |
| Fl .....                             | trace  | ----     | ----  | ----  |
| MnO .....                            | trace  | trace    | .47   | trace |
| BaO .....                            | .60    | not det. | ----  | ----  |
| SrO .....                            | .16    | not det. | ----  | ----  |
| Li <sub>2</sub> O .....              | trace  | trace    | ----  | ----  |
|                                      | 100.42 | 99.86    | 99.83 | 99.46 |
| O=Cl .....                           | .05    | .03      |       |       |
|                                      | 100.37 | 99.83    |       |       |

I. Tinguait dike from head of Bean Creek, Bearpaw Mountains, Montana. H. N. Stokes anal.

II. Tinguait dike from Cone Butte, Judith Mountains, Montana. L. V. Pirsson anal.

III. Tinguait dike from Hedrum, South Norway (Brögger Grorudit-Tinguit Serie, p. 113). G. Paykull anal.

IV. Tinguait dike, Njurjapachk Umptek Kola (Ramsay & Hackmann, Neph. Syen. Gebiet Kola Fennia, II. No. 2, 1894, p. 158). K. Kjellin anal.

The marked feature of this analysis is the preponderance of potash over soda; in this respect the rock differs markedly from similar types investigated elsewhere, as may be seen by comparison with the other analyses given.

The only rock that we can compare with it is that of a dike of tinguait from Cone Butte in the Judith Mountains, another of the outlying mountain groups of central Montana; the specimen was collected and briefly described by E. S. Dana.\*

\* Rep. Reconnaissance Carroll, Montana, to Yellowstone Park in 1875, Wm. Ludlow, War Dept. Washington, 1876, p. 105.

We owe the opportunity of examining and analyzing it to the kindness of Professor Dana, and we hope to give a full account of it at another time in connection with a description of the geology and petrography of these mountains; the analysis introduced here for comparison shows a remarkable similarity in the relations of the alkalis, a regional peculiarity. They are potash tinguaites.

It might have been expected that in a rock containing such a high potash percentage, leucite would have formed; it does not, however, occur, and all of this potash is present as the orthoclase molecule, which explains clearly the sanidine-like feldspars.

The amount of lime and magnesia is somewhat higher than these rocks usually contain; it is all present as the diopside molecule, as shown below.

If we take the chief rock-making oxides shown in the analysis reduced to 100 per cent, with the molecular proportions they yield, these ratios will furnish the table of mineral molecules given below, and the chemical composition of a rock so composed is shown in the calculated theory. It will be noticed that there are no differences except in the case of the soda, which shows that the calculated composition agrees correctly

|                                | Found. | Molec.<br>Ratio. | Calc. | Mineral Composition.                             |       |
|--------------------------------|--------|------------------|-------|--|-------|
| SiO <sub>2</sub>               | 58.94  | .9823            | 58.98 | Diopside Ca(Mg Fe)Si <sub>2</sub> O <sub>6</sub> | 20.6  |
| Al <sub>2</sub> O <sub>3</sub> | 15.80  | .1534            | 15.80 | Ægirite NaFe Si <sub>3</sub> O <sub>6</sub>      | 13.6  |
| Fe <sub>2</sub> O <sub>3</sub> | 5.00   | .0312            | 5.00  | Orthoclase KAl Si <sub>3</sub> O <sub>8</sub>    | 44.4  |
| FeO                            | .89    | .0123            | .89   | Albite Na Al Si <sub>3</sub> O <sub>8</sub>      | 12.1  |
| MgO                            | 1.41   | .0352            | 1.41  | Nephelite Na Al SiO <sub>4</sub>                 | 9.3   |
| CaO                            | 2.66   | .0475            | 2.66  |  |       |
| Na <sub>2</sub> O              | 5.62   | .0905            | 5.01  | Total  | 100.0 |
| K <sub>2</sub> O               | 9.68   | .1024            | 9.68  |  |       |

with everything in the analysis except with this element, which is a little too high; this is because the small amount of soda which goes with the carbon dioxide to form cancrinite and with the chlorine to form sodalite has not been deducted; it is just sufficient to satisfy them.

It appears at first peculiar that a rock containing so much soda should have so little of the albite molecule present; this is a result of the fact that a large amount had been exhausted by the production of ægirite before the feldspars commenced forming, as we have shown above; later the amount of silica was so low that nephelite was forced to form. Probably a little of the potash is with the nephelite and the amount of albite is somewhat higher, but this will make no essential difference. It will be noticed in the molecular ratios that the



lime, magnesia, and ferrous iron are exactly balanced for the pyroxene molecule, which is here called diopside.

*Quartz-tinguaite-porphyry.*—West of the Wind Butte core the hardened shales of the contact zone are cut by numerous dikes. Several of these consist of a minette-like type which disintegrates rapidly, so that the presence of the dike can only be recognized by the nature of the soil. Prospect pits have been sunk upon a dike of this micaceous rock, which is locally decomposed, of a white or yellowish or rusty color, and is said by miners to have an assay value of \$4 per ton. The other dikes are green porphyritic tinguaitic rocks of varying types. The usual variety is a *quartz-tinguaite-porphyry*. A fresh fracture shows a dense tough groundmass of a clear light-green color, in which are imbedded small square phenocrysts of white feldspar. The latter are equidimensional and average 1 to 2<sup>mm</sup> in diameter; they are so thickly crowded that there appears almost as much feldspar as groundmass. A few of them are much larger than the average and are of tabular habit. With the lens a very few, minute, black augites can be seen in the groundmass.

The study of the thin section shows the rock to be of very simple composition, soda-orthoclase and ægirite-augite phenocrysts lying in a groundmass of alkali feldspar, quartz, and ægirite microlites. The feldspar phenocrysts have the mottled moiré appearance and the albite microlites as inclusions described in detail in our former paper under the syenite-porphyry of Gray Butte; they have been studied, but demand no further notice. The ægirite-augite phenocrysts are rather deficient in the ægirite molecule, otherwise they are of the usual type. The groundmass, which is of extremely fine grain, is thoroughly allotriomorphic in structure and the amount of quartz is considerable; the ægirite is scattered through it in such great quantities, as slender needle-like microlites, that the section has a mossy appearance.

The rock in thin section very closely resembles the gronrudite of Brögger from Grorud, only that the groundmass has a greater degree of granularity. The occurrence of these quartz-tinguaite in the Bearpaw mountains we have already indicated, and one of them has been described.\* The rock here mentioned is closely similar to the one previously described, only that in the former specimen the feldspars are uniformly larger and more tabular in their habit.

*Pseudo-leucite-sodalite-tinguaite.*—About a half mile beyond the southern boundary of the Beaver Creek stock a dike of peculiar bright green rock was observed cutting the altered

\* This Jour., vol. 1, p. 394, 1895.

sedimentary strata. This dike appears at intervals as a wall, standing in relief above the slopes beneath the great cliffs east of the stream. On the west it forms a conspicuous reef in the slope immediately above the creek bottom, but was not seen beyond. The dike is 5 feet wide and cuts rusty, massively fracturing hornstones that belong to the contact zone and dip at  $15^{\circ}$  up stream. The dike crosses the creek at right angles, but trends toward the stock. The western exposure forms a flat-topped wall that is but a few hundred feet long, shown in the accompanying sketch (fig. 3) in which the tilted sedimentary beds are seen to the left of the dike.

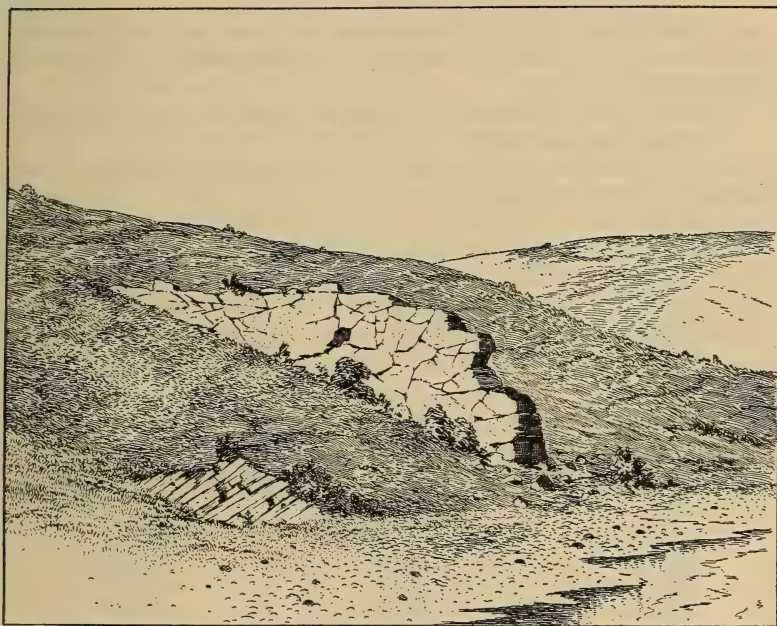


FIG. 3. Dike of Tinguaitite on Beaver Creek, Bearpaw Mts.

The dike has a nearly vertical contact, but sends a little stringer out into the shale, as shown in fig. 4. At the contact the shales are highly altered for a few inches.

The dike consists of a bright green porphyritic rock of quite unusual character. It is a *pseudo-leucite sodalite tinguaitite*. The specimen and section show that this is the rock which has already been described by us\* from a drift pebble collected on the Missouri River. The specimens and sections are so absolutely identical, and the peculiarities of the type so

\* This Jour., vol. I, p. 394, 1895.

marked, that there cannot be a possibility of doubt upon this point. It consists of large, white, well-formed pseudo-leucites and smaller, white or pinkish sodalites and noseans thickly crowded in a dense, dark green groundmass. An occasional augite or feldspar phenocryst is also seen. The microscope shows the pseudo-leucites to be made up of alkali-feldspar and nephelite. The groundmass is composed of alkali-feldspar, nephelite, and ægirite needles. For further details the reader is referred to the former paper. A more detailed study of the feldspars shows them probably to be soda orthoclases or anorthoclase. They have, moreover, the watered, wavy, moiré appearance which has been found to be so characteristic a microstructure in the alkali feldspars of these rocks, and which is in reality a very useful diagnostic character.

The same rare minerals of unknown character are also present in the new material.

A complete analysis of this interesting type, by Dr. H. N. Stokes, is given in No. I.

|                                      | I.     | II.    | Ia.   |
|--------------------------------------|--------|--------|-------|
| SiO <sub>2</sub> .....               | 51.93  | 52.91  | .8655 |
| Al <sub>2</sub> O <sub>3</sub> ..... | 20.29  | 19.49  | .1970 |
| Fe <sub>2</sub> O <sub>3</sub> ..... | 3.59   | 4.78   | .0224 |
| FeO .....                            | 1.20   | 2.05   | .0166 |
| MgO .....                            | .22    | .29    | .0055 |
| CaO .....                            | 1.65   | 2.47   | .0294 |
| Na <sub>2</sub> O .....              | 8.49   | 7.13   | .1367 |
| K <sub>2</sub> O .....               | 9.81   | 7.88   | .1041 |
| H <sub>2</sub> O—110° .....          | .10    | 1.19   |       |
| H <sub>2</sub> O + 110° .....        | .99    |        |       |
| TiO <sub>2</sub> .....               | .20    | none   | .0020 |
| CO <sub>2</sub> .....                | .25    | none   | .0057 |
| Fl .....                             | .27    | .48    | .0142 |
| Cl .....                             | .70    | .53    | .0196 |
| SO <sub>3</sub> .....                | .67    | .52    | .0070 |
| P <sub>2</sub> O <sub>5</sub> .....  | .06    | trace  |       |
| MnO .....                            | trace  | .44    |       |
| SrO .....                            | .07    | .09    |       |
| BaO .....                            | .09    | ----   |       |
| Li <sub>2</sub> O .....              | trace  | trace  |       |
|                                      | <hr/>  | <hr/>  |       |
|                                      | 100.58 | 100.25 |       |
| O=Cl, Fl .....                       | .27    | .12    |       |
|                                      | <hr/>  | <hr/>  |       |
|                                      | 100.31 | 100.13 |       |

I. Leucite tinguaité, Beaver Creek, Bearpaw Mountains, Montana. H. N. Stokes anal.



II. Leucite tinguaita, Magnet Cove, Arkansas. J. F. Williams anal. (Igneous Rocks of Ark., Ann. Rep., 1890, vol. ii, p. 287.)

Ia. Molecular proportions of No. I.

The interesting feature of this analysis is the rather low silica and great quantities of alkalis. A consideration of the molecular proportions shows that there is considerably more than enough to furnish the proportion  $R_2O : R_2O_3 = 1 : 1$ , and this excess is, of course, due to the presence of the sodalite, which forms 10 per cent. of the total weight of the rock. The sulphuric anhydride proves that the nosean molecule is certainly present and forms about 4.3 per cent of the rock. The minerals being fresh, clear, and colorless, it is impossible to tell it from sodalite in the section. The minute amount of phosphoric anhydride shows that the fluorine is to be referred to the fluorite present; after deducting enough lime for this small amount of fluorite, the remainder exactly balances the lime and magnesia and is present as the diopside molecule. Hence the feldspars are entirely alkaline. After deducting enough soda to turn the ferric iron into ægirite and to satisfy the acid radicals, other than silica, which are present, a consideration of the remaining molecular proportions shows clearly that the orthoclase molecule is by far the dominating feldspar present, the soda being mostly taken up by nephelite and sodalite.

Taking these facts into consideration and regarding the nosean as a pure soda compound, the following calculation has been made of the proportion of the various mineral molecules present:

|            |                              |       |
|------------|------------------------------|-------|
| Diopside   | $Ca(Mg,Fe)Si_2O_6$           | 5.4   |
| Ægirite    | $NaFeSi_3O_8$                | 9.2   |
| Sodalite   | $Na_4Al_3Si_3O_{12}NaCl$     | 9.8   |
| Nosean     | $Na_4Al_4Si_4O_{16}Na_2SO_4$ | 4.2   |
| Nephelite  | $NaAlSiO_4$                  | 16.2  |
| Orthoclase | $KAlSi_3O_8$                 | 54.5  |
| Fluorite   | $CaF_2$                      | .7    |
|            |                              | <hr/> |
|            |                              | 100.0 |

This, of course, is approximate, as a small portion of the potash is probably present with the soda in the nephelite, while conversely the feldspar, as already stated, contains some soda. Relatively the amounts given in the table may be taken as indicating closely the average composition of the rock.

For comparison we have introduced the analysis of a similar type of rock from Arkansas, and it will be seen that on the

whole the agreement is very satisfactory; the Arkansas type does not contain so much sodalite and it does not in consequence contain so much alkali. An analysis of the Brazilian rock containing pseudo-leucites described by Graeff\* and Hussak,† we have not been able to find.

In examining the face of the dike carefully the pseudo-leucite phenocrysts are seen to present the distribution indicated in the accompanying diagram (fig. 4). In the main body of the dike these crystals occur somewhat abundantly scattered through the rock, but about 3 inches from the actual contact there is a band running parallel to the contact plane



FIG. 4. Cross-section of contact of tinguaita dike and shales. Shows distribution of pseudo-leucite phenocrysts.

and from 4 to 6 inches wide, in which the rock shows no leucite phenocrysts. Outside of these bands, which occur on both sides of the dike, the rock for 2 to 3 inches from the contact is quite like that of the main body of the dike, and the leucite phenocrysts occur perhaps somewhat more abundantly, even at the very contact surface itself. The rock forming the dense band just noted is quite like that of the main mass of the dike, except for the absence of the pseudo-leucites. The thin section shows sodalites of very idiomorphic form, and the groundmass the same mossy appearance from the innumerable fine needles of ægirite. The contact of the dike with the shales shows that the pseudo-leucites and sodalites occur up to the very plane of contact and of the same size as in the main portion of the dike. The groundmass in which they lie has, however, at the contact a very different character from the main type, and this would seem to indicate clearly that these phenocrysts were of intratelluric formation and had been brought up in the ascending magma. The groundmass appears with low powers of a uniform olive-green color, and does not act upon polarized light. With the highest powers it appears full of tiny shreds, fibers, and scales of almost sub-microscopic fineness; they do not appear to react on light, and the base seems most probably here composed of glass and filled with globulitic bodies recalling the much disputed microfel-site. Scattered through this are many minute sodalites, with numbers of the large-sized ones. The pseudo-leucite seen in the section shows so well the radial arrangement of the feld-

\* Jahrb. für Min. 1887, vol. ii, p. 257.

† Ibid 1890, vol. i, p. 167.

spars around some object, with the palisade structure around the edge, that we have thought best to give a drawing of it (fig. 5), which shows also the character of the rock in a diagrammatic way; one pseudo-leucite is shown, with a number of sodalites and a prism or two of augite lying in the dark mottled base with the contact with the altered shale.

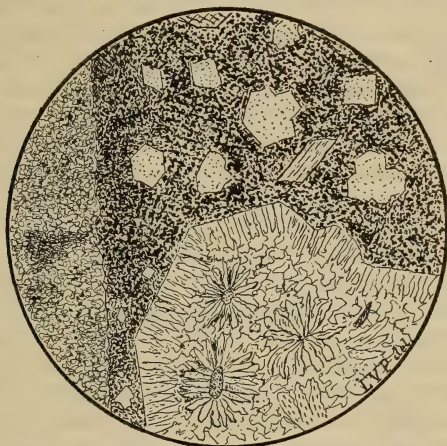


FIG. 5. Contact of altered shale and tinguaitite.

The shale at the contact is altered to a dense, black, tough hornstone. In the section it is found composed mostly of sub-angular fragments of quartz but with other fine mineral particles present and mostly of an indeterminate nature; much of it appears like masses of kaolin leaves, seen in an altered feldspar; in other pieces the grain is coarser and the rock is composed mainly of quartz grains and particles of a pleochroic brown mica. As is so often the case, there appears to be some alteration directly at the contact, where the minerals are not as fresh as further out in the dike. In addition to the varieties of tinguaites described, a few others were collected from the local drift of the mountains.

The result of the study of the geology and rocks of this hitherto unknown mountain group, of which only a rapid reconnaissance has been made, presented in this series of articles, shows the region to be one of peculiarly great interest to the student of volcanic geology and the petrographer. We may confidently expect that our future mapping and detailed study of the district will afford a rich harvest of facts important to the science of the petrology of igneous rocks.

Washington and New Haven, April, 1896.



ART. XXV.—*Is the land around Hudson Bay at present rising?* by J. BURR TYRRELL, of the Geological Survey of Canada.

IN the March number of this Journal, Dr. Robert Bell has a paper entitled "Proofs of the rising of the land around Hudson Bay," in which he criticises a statement made by me in the Geological Magazine for September, 1894, "that at Fort Churchill the land and sea have reached conditions of comparative equilibrium," and in which he endeavours to prove that "the elevation (of the land) is still going on," and to strengthen the statements in his "various official reports on the geology of those regions from 1875 to 1886," which are "that the waters of Hudson's Bay are receding between 5 and 10 feet in a century,"\* and particularly "that the relative level of the sea and land in this vicinity (Port Churchill) is changing at the rate of about 7 feet in a century."†

As my previous paper was rather a brief statement of results, published in advance of an official report, than a full account of post-glacial and recent phenomena at Churchill, it may be interesting to consider, a little more in detail, some observations which seem to me to bear on the question of the present rising or stability of the land to the west of Hudson Bay.

That there has been an elevation of the land of several hundred feet in post-glacial times is just as clearly apparent on the shores of Hudson Bay as it is in the valley of the St. Lawrence River, and the evidences in favor of that elevation will not here be discussed.

Fort Churchill, situated near the mouth of Churchill River, which flows into the west side of Hudson Bay in north latitude  $58^{\circ} 47'$ , has been occupied as a trading port of the Hudson Bay Company for 180 years, and it is reasonable to expect to find here some evidence of the relative position of land and sea a reasonably long time ago.

In 1733 the Hudson Bay Company began building the massive stone fortification, which they called Fort Prince of Wales, on the summit of the low point west of the entrance to Churchill River. It is 250 feet square between the angles of the bastions, and its stone walls are 42 feet thick. It is surrounded by a gravel-covered terrace, and the base of its walls are now 17 feet above ordinary spring tides, and 6 feet above the top of the shingle beach that is now regularly washed by

\* Rep. of Prog. Geol. Sur. Can., 1877-78, pp. 25 CC. and 33 C.

† Ibid., 1878-79, p. 21 C.

the storm waves at high tide. Had the land in 1733 been 11 feet lower than it is at present, storm waves at the ordinary flood tides would have regularly washed over the point, and it is not likely that a structure of any kind would have then been built.

In his account of Hudson Bay, published in 1744, Sir Arthur Dobbs, a man who has made himself very well acquainted with the geography of Hudson's Bay, states that Fort Prince of Wales is built "upon an eminence 40 feet high,"\* a perfectly natural exaggeration for a man looking at the fort in its present position, 25 feet above mean tide level, but hardly intelligible if the land was 10 or 11 feet lower than at present, and the fort was but 15 feet above mean tide, and less than 8 feet above the top of spring tide.

For several years between 1733 and 1747 Joseph Robson, an engineer, was stationed at Churchill to superintend the building of this fort. About 1746 he made a survey of the river for 10 miles up from its mouth, drafting a map which was published by him in 1752.† This map, of which a reduced copy is shown on page 202, shows the river at high and low water, and the rocks and low marshy ground around it. The conditions here shown are just such as exist at the present time. The Mission House is now where *Old Fort* is marked on the map, and the Hudson Bay Company's fur-trading post is a few hundred yards farther towards the southwest. A gently sloping strong flat, dry at low water, extends out for about a mile to the low water channel, and low marshy ground, but slightly above the level of high water, extends back from high water mark. If the land had been even a few feet lower in 1746 then it is at present, much of the marshy ground west and southwest of the lagoon would have been covered with water at high tide, while if it had been 10 feet lower the low water mark would have been close to the foot of the "High Rocks" north of the *Old Fort*, and only a couple of hundred yards out from the shore opposite the present fur-trading post.

On the same map the promontory on which Fort Prince of Wales is built is shown connected by a narrow neck of land to the main shore, and not as an island as stated by Dr. Bell, and as this was doubtless the low rough rocky neck which in the same place still rises a very few feet above the water, it seems to have been necessary to build a bridge or causeway over which stones for the fort could be hauled. The place of this bridge, which seems to have crossed the head of the bay south

\* An account of the Countries adjoining to Hudson's Bay, by Arthur Dobbs, Esq., London, 1744, p. 55.

† An account of six years residence in Hudson's Bay, by Joseph Robson, London, 1752.

of the narrow neck marked on the map, has since been taken by a sandy bar built along the bank of the river by the currents caused by the ebb and flow of the tide.



Sloops Cove is a little bay on the west side of the river, two miles above Old Fort Prince of Wales. It was so called from having been the wintering harbor of the small sloops kept here during the 18th century for the purpose of trading with the Eskimo to the north. The cove is 100 paces long and 50 paces wide, and on each side are smooth well-glaciated rocks of green arkose, rising, at first steeply, and afterwards more gently, to about 25 feet above high water mark. At the back is a grass-covered bar of sand and gravel 8 feet high, between the two rocky hills, and separating the cove from a wide flat still covered with water at high tide as it was in 1746. The bottom of the cove, almost up to high tide level, is composed of a fine soft silt brought in by the river. Across its mouth is a gravel bar through which project two low bosses of rock. Between these the water now drains out of the cove as the tide recedes, leaving it dry at low tide, and not "full of water" as stated by Dr. Bell. North of these bosses is a larger gap which has been blocked by a dam of pieces of timber and large masses of rock, many of which have been blasted from some place in the vicinity, perhaps from south of the knolls, where the gravel bar has since been formed. Outside the mouth of the cove Robson's map shows the low water mark a quarter of a mile distant. When seen by the writer in 1894 the low water mark did not seem to be so far out.



It is difficult to understand Dr. Bell's statement that Sloops Cove is "a small elliptical pond (?) connecting with the lagoon by a very narrow entrance, through which the water barely passes at high tide," for in the gap at the mouth of the cove there are now four feet of water at the top of spring tide, but it is quite probable that before the dam was built and the gravel bar was formed the entrance may have been considerably deeper. Robson's map does not show the gravel bar at either end, and if they did not exist in 1746 the fine soft silt that now forms the bottom would not have been there either, for the tide rushing through the gap would have scoured it down to the hard till or rock. Perhaps the building of the dam at the mouth of the cove, preventing this tidal scour, has been the chief reason why it has since silted up.

It is difficult to find a good wintering place for a small craft in Churchill harbor, as the ice may shift and break the anchor chains and moorings, and carry the ship on the top of large boulders; and since such a ship would be perfectly safe when once it had been floated into Sloops Cove, considerable exertion would doubtless be made to get it there. In addition to the sloops of the Hudson Bay Company, local tradition has it that the *Furnace* and *Discovery*, two small ships sent to look for the northwest passage, here spent the winter of 1741-42, and the words *Furnace & Discovery 1741* cut in the face of the smooth rock on the north side of the cove, would indicate that this tradition is correct. The *Furnace*, the largest of these two vessels, is said by Forster to have been a "sloop or bombketch" and probably had a draft of about eight or nine feet, which, in such a wide craft, could be lightened to six feet or less. That they were able to take the ships into and out of dock at high tide only is clearly shown by Robson's map, and also by the statement of Captain Middleton of the *Furnace*, that they on "June 9th and 10th (spring tide after the full moon of June 6th, old style) got the ship out of the dock and moored her." \*

If the deepest part of the mouth of the cove can now be seen, and if the ships required six feet of water to float them into it, there would here be evidence of the rise of the land to the extent of two feet in the last century and a half, but, as neither of these two points is certain, the evidence is hardly worth considering at present.

On the rocky walls of the cove, planed smooth by a glacier from the southwest, many names have been engraved, and now appear as fresh as if cut but yesterday. Among these the one of greatest historic interest is that of *Sl. Hearne*, the discoverer of the Coppermine River, who, on Wednesday, *July ye 1*,

\* Dobbs' Hudson Bay, p. 17.

1767, two years before he started on his memorable journey to the Northern Ocean, appears to have sat here with hammer and chisel, beguiling the long hours of his tedious solitude by engraving his name among many others on this lonely promontory. But other names are of more interest in connection with the question of the rise or fall of the land.

During the winter the bottom of the cove becomes filled with ice, up to the level of the top of the highest spring tide of that winter, probably a foot above the level of ordinary spring tide, which is given on the Admiralty Chart at 15 feet 5 inches. At times extraordinary tides rise four feet higher than this, the heights of these latter tides having been pointed out to me on the wharf in front of Fort Churchill. On the 2d of November, 1893, the cove was filled with ice up to the level of the last spring tide, about an ordinary one, and the heights above the ice of the following names were measured and are given opposite to them :—

|  |             |
|--|-------------|
| James Walker, May y <sup>e</sup> 27, 1753 .....  | 7 ft.       |
| Guilford Long, May y <sup>e</sup> 27, 1753 ..... | 7 ft.       |
| J. Marley, 1748 .....                            | 6½ ft.      |
| J. Horner, 1746 .....                            | 6 ft.       |
| J. Wood, 1757 .....                              | 6 ft.       |
| Furnace & Discovery, 1741 .....                  | 3 ft. 3 in. |

As the ice does not break up in Churchill Harbor, on an average, until the 19th of June, the two names first mentioned were doubtless cut while the ice was in the cove at its highest winter level, which at the present time would not be more than six feet below them, and the surface of the snow would probably be still higher. Since the names would in all probability be cut not less than two feet above the surface of the snow or ice, and could not be cut below it, they indicate that the water was about as high then as now, and they prove quite conclusively that it was not ten feet higher in 1753 than it is now, as it would have been if there had been a rise of the land of seven feet in a century.

It does not appear in what months the names of the other men were engraved, but probably in the long days of spring, before the ice had gone out of the river, and the busy summer of trade, fishing and building had begun.

The *Furnace* and *Discovery* reached Churchill in the summer of 1741. Their names are cut in the almost vertical face of the smooth rock, but whether they were cut before the bottom of the cove was covered with ice or not is not known.

Besides the evidence furnished by the above mentioned names, a number of rings have been set in the rock at various heights for the moorings of the ships or sloops. Those five

feet or more above the ice of November 2d, 1893, are still firm and strong, while some two feet and a half above the ice have been almost entirely rusted away. The former have evidently been comparatively free from the influence of the salt water, while the latter have been wet by high tides, and even in this little sheltered spot have been splashed by the spray in heavy storms.

The positions and states of preservation of these rings, which were doubtless placed there in the middle of the 18th century, when the masons were building Fort Prince of Wales, and when the sloops regularly wintered here, clearly indicate that there has been no great change in the relative heights of land and water since they were set into the rock.

After carefully considering what we know of the present and former height of the water around Fort Prince of Wales, and the records left on the rocky wall of Sloops Cove, but more especially after comparing the map of the lagoon at the mouth of Churchill River made in 1746 by Joseph Robson, an engineer, with the lagoon as it exists at present, I am forced to conclude that evidence of the rising of the land, drawn from the fresh appearance of the post-glacial beaches, from the height of driftwood, from the silting of the mouths of rivers that flow swiftly through alluvial plains or from the tales of the Indians, who would doubtless regard the formation of a sand-bar as the receding of the waters, is delusion, and that the post-glacial uplift of this portion of the shore of Hudson Bay has virtually ceased, and that the land has now reached a stable, or almost stable, condition.

ART. XXVI.—*Principles of North American pre-Cambrian Geology*; by CHARLES RICHARD VAN HISE. *With an Appendix on Flow and Fracture of Rocks as Related to Structure*; by LEANDER MILLER HOSKINS. Sixteenth Annual Report, U. S. Geol Survey, Part I, pp. 571-874.

[Author's abstract.]

THE design of the paper is (1) to give a partial discussion of principles applicable to geological work among the pre-Cambrian rocks of North America, and (2) to give an historical account of the North American pre-Cambrian, and to point out the principles illustrated in the various regions. The first is considered in Part I, the second in Part II.

#### PART I.—*Discussion of Principles.*

The discussion of principles is supplementary to that in textbooks rather than a full treatment. Since fossils are not avail-



able for the study of pre-Cambrian rocks, it is necessary to develop methods of geological work based upon physical phenomena. The subjects considered under physical geology are the general movements of rock material under deformation, folds, cleavage and fissility, joints, faults, autoclastic rocks, metamorphism of rocks, and stratigraphy.

*Deformation of Rocks.*—It is shown that the outer part of the earth may be divided into three zones: (1) An upper zone of fracture; (2) a middle zone of combined fracture and plasticity; (3) a lower zone of plasticity.

1. Rocks under less weight than their ultimate strength when rapidly deformed are in the zone of fracture. That is, when rocks under such conditions are deformed they break, and crevices small or great separate the broken parts. The fractured rocks may be jointed, faulted, or brecciated in a simple or a complex manner. The fractures may be far apart and of great size and extent, or near together and of small size and extent. Innumerable parallel fractures may occur in the same direction, when, as shown later, the rocks develop a parting, or fissility. In extreme cases of fracturing the rocks become autoclastic, or are broken into innumerable fragments by the forces of deformation. These fragments may be rounded, and such rocks resemble ordinary elastic rocks. The lower limit of this zone of fracture is at different depths for different rocks, and at different depths for the same rock under different conditions of deformation. However, from computations by Prof. L. M. Hoskins it is concluded that it is highly probable that at a depth of 10,000 meters, not only do no crevices permanently exist in the earth, but the rocks are in such a condition that actual welding of the fractured parts would soon take place, supposing fracture to occur.

3. Rocks buried to such a depth that the weight of the superincumbent strata exceeds their ultimate strength are in the zone of plasticity and flowage. These are the conditions of folding, for permanent perfect flexure is possible only by flowage of material. It is a contradiction to suppose that cracks and crevices can form under these conditions. Were it possible for an opening to be made in any way, under the hypothesis, the rock would flow toward the opening and close it. This is the deep-seated zone of perfect folding. In the folding there is necessarily readjustment between the strata and rearrangement within each of the strata. If the beds are not changed in thickness, the folds must die out with increased depth. If they remain of similar form, this is only possible by a thickening on the anticlines and synclines and a thinning on the limbs.

2. Since the boundary between the zone of fracture and the

zone of flowage is at a different depth for two rocks of unequal strength and for the same rock under different conditions during deformation, there is a zone of combined fracture and flowage. In a set of heterogeneous beds, upper, weak strata may be in the zone of folding, while lower and stronger strata may be in the zone of fracture. It is believed that the zone of combined fracture and flowage is probably 5,000 meters thick. The three zones of fracturing, of fracturing and flowage, and of flowage grade into one another.

*Analysis of Folds.*—As ordinarily treated, folds are considered as simple flexures in two dimensions. As they occur in nature, many folds are complex flexures in three dimensions. Flexures in two dimensions may be simple or composite, and the folds may be called simple folds or composite folds. Flexures in three dimensions may be called complex folds. Following Margerie and Heim, simple folds are classified into upright, inclined, overturned, and recumbent. Any one of these folds may be ordinary, isoclinal, or fan-shaped.

The greatest composite folds of the earth's crust, following Dana, are called geanticlines and geosynclines. In the formation of these folds gravity is the predominant force, whereas in ordinary composite folds thrust is an important or predominant force,—although in all folds thrust and gravity work together. Composite folds are divided into normal and abnormal. Both normal and abnormal folds are divided into upright, inclined, and overturned anticlinoria and synclinoria. In normal anticlinoria the axial planes of the secondary folds on opposite sides of the crest converge downward. In normal synclinoria the axial planes of the secondary folds on opposite sides of the trough diverge downward. In abnormal anticlinoria the axial planes on opposite sides of the crest diverge downward, and in abnormal synclinoria the axial planes on opposite sides of the trough converge downward. It is shown in the case of normal folds that, as a result of the action of the forces, accompanied with normal adjustment, the axial planes of the secondary folds have the attitudes above given. In the case of abnormal folds the readjustment is concentrated along certain zones, and the axial planes are rotated from their ordinary position to the positions above given. In case of axial planes of a set of folds in a mountain system inclined in the same direction the folds are called monoclinial. Overthrust monoclinial folds are defined as those in which the axial planes dip toward the forces producing them, and underthrust folds are defined as those in which the axial planes dip away from the forces producing them. In the majority of cases it is held that monoclinial folds are overthrust folds.

If horizontal compressive forces are sufficiently strong to

produce deformation in two directions at right angles to each other, this results in the production of complex folds. The folds produced by the major thrust may be called major or longitudinal folds, and the folds produced by the minor thrust, minor or transverse folds. The methods of determining that a district is one of complex folding and the character of the observations which should be made in such a district are fully discussed. In the production of simple, composite, or complex folds the movements may have been continuous or discontinuous.

*Cleavage and Fissility.*—The property of cleavage in rocks is defined as a capacity present in some rocks to break in certain directions more easily than in others. Fissility is defined as a structure in some rocks by virtue of which in a state of nature they are already separated into parallel laminæ. The term fissility thus complements cleavage, and the two are included under cleavage as ordinarily defined. It is held that cleavage is a deep-seated phenomenon of the zone of flowage, and that fissility is a more superficial phenomenon of the zone of fracture.

From a discussion of the phenomena it is concluded that rock cleavage as above defined is due to the arrangement of the mineral particles with their longer diameters or readiest cleavage, or both, in a common direction, and that this arrangement is caused, first and most important, by parallel development of new minerals; second, by the flattening and parallel rotation of old and new mineral particles; and third, and of least importance, by the rotation into approximately parallel positions of random original particles. From the fact that frequently cleavage is everywhere parallel to intrusive batholites, from the fact that flattened rock particles are in the plane of cleavage, and from the frequent transverse relations of the structure and the bedding, it is concluded that cleavage develops in a plane normal to the greatest pressure. In homogeneous rocks the structure may vary from perpendicular to parallel to the bedding.

Fissility, being due to rupture, is produced along shearing planes, and is, therefore, inclined to the direction of greatest pressure. Cleavage and fissility intersecting bedding are called cross cleavage and cross fissility, and those parallel to the bedding are called parallel cleavage and parallel fissility.

In heterogeneous rocks the readjustment between the beds may rotate the cleavage from its ordinary position, but, as shown by Prof. Hoskins, at any moment the cleavage is developing in the direction of greatest shortening, or at right angles to the greatest pressure. The result of the rotation of cleavage is to bring it more nearly in accordance with bedding. As the readjustment and consequent rotation is greater in a weaker



than in a stronger bed, it follows that cleavage in a soft layer more nearly accords with bedding than it does in a hard layer. Further, in the more plastic beds cleavage may be developed, and may be absent or imperfect in the more rigid beds. The change in direction may be abrupt, but if there is a gradation between the hard and soft layer the cross cleavage of the hard stratum may vary by a curve into the nearly parallel cleavage of the soft stratum. Since on opposite sides of a fold the readjustment is in opposite directions, the cleavage dips in opposite directions. On opposite sides of an anticline the cleavage usually diverges downward; on opposite sides of a syncline it usually converges downward. In areas of much overturned monoclinal folds the readjustment between the layers is all in the same direction, and hence the cleavage is rotated in the same direction, and is monoclinal throughout.

Fissility in heterogeneous rocks may develop in two directions at the same time. In a common case one of these is in shearing planes, and the other normal to tensile planes. The fissility formed in shearing planes may have the same relations to the bedding of hard and weak layers as does cleavage. As rocks in the deep-seated zone in which cleavage develops must pass through the zone of combined fracture and flowage and into the zone of fracture, before they reach the surface, it frequently happens that fissility is developed in rocks which had a prior cleavage. As the cleavage planes under these conditions are likely to be shearing planes, the fractures of fissility are likely to be controlled in direction by the previous cleavage, whether it is the direction of maximum tangential stress or not. It is, therefore, concluded that fissility developing in the shearing planes is usually secondary to cleavage developed in the normal planes. In those cases in which the folding is extreme, both the primary and secondary structures may become nearly accordant upon the limbs of folds, but are transverse to each other on the anticlines. If the turns in the strata are very sharp at these places, the discrepancy between the two structures may be overlooked, and it may be concluded that bedding and secondary structures are everywhere accordant. Such a mistake may result in a great over-estimate of the thickness of strata, and give erroneous ideas of structure.

When cleavage and fissility develop there are many slightly separated movements of small degree. When a thrust fault develops there is a single major movement. After a secondary structure has formed in a region, within the cracks of fissility or along the planes of weakness of cleavage, there may be secondary impregnations or injections, and thus banded rocks may owe their structure to fissility and secondary impregnations or injections, or both, and the bands may or may not accord with an original structure.

The foregoing principles are applied to the Appalachian and certain other regions. Much of the Appalachian region is one of monoclinal folding, and, therefore, one of monoclinal cleavage, and of monoclinal fissility secondary to cleavage. In areas in which there have been secondary impregnations and injections there is a secondary monoclinal banding. A similar explanation is applied to the monoclinal banding of the Archean gneiss in great areas in Canada and in southwestern Montana.

*Joints.*—Joints may be classified into tension joints and compression joints. The first ordinarily develop in planes normal to the tensile forces, the second develop in the shearing planes inclined to the compressive forces. Tension joints are often produced along the crowns of the anticlines in areas of simple folds. In areas of complex folds tension joints may be produced in two directions at right angles to each other. Compression joints, as explained by Daubrée and Becker, form along shearing planes, and are in the simplest case produced simultaneously in two directions nearly at right angles to each other. Joints, implying as they do openings in the rocks, are necessarily confined to the outer zone of fracture and the middle zone of fracture and flowage.

*Faults.*—Faults may be classified into normal or gravity faults and reverse or thrust faults. The first class is ordinarily produced under conditions of tension, the second under conditions of compression. Normal or gravity faults result in the dilation, thrust faults result in the contraction of the part of the crust of the earth affected by them. It is shown that the average deformation of a region may be the same whether it be by a few great faults with little or no fissility, by more frequent lesser faults with or without fissility, by faults and overfolds with or without both cleavage and fissility, or by folding with or without faults and cleavage; also that there is every gradation between faulting and fissility, and probably every gradation between faulting and cleavage. Faults are limited in horizontal as well as in vertical extent, and are usually confined to the zones of fracture and of fracture and flowage. Probably most faults at sufficient depth pass into flexures, and deeper down these flexures may die out.

Folds, cleavage, fissility, joints, and faults are regarded as the conjoint products of thrust and gravity. Similar forces acting upon heterogeneous rocks under various conditions produce diverse phenomena. Thus several classes of phenomena which are often treated as independent and unconnected are genetically connected. In the zone of combined flowage and fracture all the structures occur together in a complex manner, the particular combination of phenomena depending upon the relative thickness, strength, and brittleness of the rock beds concerned, and upon the forces at work.

*Autoclastic Rocks.*—When rocks are folded by strong orogenic forces, and they are not so heavily loaded as to render them plastic, they are frequently broken into fragments, and “autoclastic” rocks are produced. The autoclastic rocks which readily show their origin may be called breccias, and those which resemble ordinary conglomerates may be called pseudo-conglomerates. Brittle rocks are the most likely to become autoclastic. Autoclastic rocks are confined to the zone of fracture and the zone of combined fracture and flowage. Pseudo-conglomerates sometimes resemble basal conglomerates. Hence criteria are described which discriminate between the two.

*Metamorphism.*—Metamorphism is used in its broad sense to cover the alteration of all classes of rocks by all processes. The prominent forces producing metamorphism are pressure, heat, and chemical affinity. Pressure may be resisted by rigidity, or may pass into mass motion. In the former case the conditions are those of static metamorphism, and the motions are molecular. In the latter case the conditions are those of dynamic metamorphism, and the motions are both molecular and mass. The heat may result from dynamic action, be obtained from liquid rock intruded from below, or from the interior of the earth by the normal increase of temperature due to depth. In the chemical changes water is the menstruum through which most of the transformations are made. It carries the materials from one place to another, and thus the composition of great masses of rock may be changed.

The chief processes of metamorphism considered are consolidation, welding, cementation, injection, metasomatism, and mashing. Consolidation is produced by the mere pressure of superincumbent strata or by the stress of thrust, so that the mineral particles are brought closer together. If rocks are so deeply buried that the superincumbent weight is beyond the crushing strength, or if they are in the zone of flowage, it is possible that the particles may become welded together. By cementation is meant the binding together of the rock particles by the infiltration of mineral material in solution and its deposition as minerals in the interstices of the rocks. By injection is meant the penetration of a rock by a molten magma. Pegmatization is believed in some cases to be due to cementation, in others to injection, and in others to a combination of the two, that is, it is thought highly probable that under sufficient pressure and at a high temperature there are all gradations between heated waters containing mineral material in solution and a magma containing water in solution. In other words, under proper conditions water and liquid rock are miscible in all proportions. From the water solutions true impregnation or cementation would take place; from the rock



solutions, true injection. Metasomatism may be defined as the process of metamorphism by which original minerals are partly or wholly altered into other minerals, or are replaced by other minerals, or are recrystallized without chemical changes, or one or all of these together. Metasomatism is considered from the point of view (1) of the alteration of the original mineral particles, (2) of the mineral particles which are produced by the process of alteration, and (3) the texture of the rock produced. Secondary mineral particles in the metamorphic rocks which show no evidence of strain are believed to have been produced by metasomatic processes under static conditions. In some cases the rocks have previously been subjected to dynamic conditions. Under mashing is included the process which is usually described in geological writings under the terms dynamic metamorphism and shearing. The schistose structure produced by mashing in the deep-seated zone of flow develops in the normal planes rather than in the shearing planes. In the zone of fracture schistosity may be in the shearing planes.

The development of each of the important pre-Cambrian metamorphic sedimentary rocks is described, and the development of the metamorphic igneous rocks is more briefly summarized. The metamorphic sedimentary and metamorphic igneous rocks are compared, and criteria are given for discriminating between the two. Among others, the conclusion is reached that the finely, regularly laminated homogeneous crystalline schists having only a single structure are usually of igneous origin.

*Stratigraphy.*—The phenomena which may be taken as evidence of bedding in the metamorphic rocks are described.

The method of formation and significance of basal conglomerates are considered. The phenomena which may be mistaken for basal conglomerates are described. These are volcanic fragmental material, erosion conglomerates derived from lavas, conglomerates formed in shallow seas by storms of exceptional violence, intraformational conglomerates, auto-clastic rocks, and pseudo-conglomerates produced by igneous intrusion.

The phenomena indicating unconformity are described. These are (1) ordinary discordance of bedding; (2) difference in the number of orogenic movements to which the series have been subjected; (3) discordance of bedding of upper series and foliation of lower; (4) relations with eruptives; (5) difference in degree of crystallization; (6) basal conglomerates; (7) general field relations. It is shown that all evidence of unconformities, even when they are marked by the most distinctive proofs in little disturbed areas, may be entirely obliterated by orogenic movements and the attending metamorphism. As a result, originally unconformable series may be thought to be

conformable. It is shown that unconformities are usually at least regional in extent, that some of them are continental, and that perhaps a few may even be intercontinental. As to the time represented by an unconformity it is concluded that a slight unconformity may mark no more than a minor part of a period; that a great unconformity probably always marks at least a major part of a period; and, finally, that a slight or great unconformity may mark eras of time.

In structural work in nonfossiliferous rocks it is concluded that unconformities give the best datum horizons from which to build up the stratigraphy in a geological province. Within a geological province, next in value to unconformities is like sequence of lithological formations in different districts. Of the least value in stratigraphy is the lithological character of a formation. Formations may vary rapidly in character, or in mediterranean seas may have a like original character for long distances. It cannot be assumed, in passing from province to province, that the unconformities are equivalent, and hence we are yet without any criteria for correlating pre-Cambrian series in different geological provinces. In the future the only ways known in which the questions of correlation between geological provinces in pre-Cambrian rocks can be certainly solved are to find fossils in the series concerned or to work out the physical history of the continents, and the more hopeful direction of attack is along the line of the physical history of the continent.

## PART II.—*Historical Geology.*

The character, origin, and delimitation of the Archean are considered. The conclusion is reached that the Archean is igneous, and represents a part of the original crust of the earth or its downward crystallization. The Algonkian is defined as including all recognizable pre-Cambrian clastics and their equivalent crystallines. The character and delimitation of the Algonkian are considered. The rock succession, correlation, and principles illustrated of each of the pre-Cambrian regions of North America are summarized. The areas considered are the Original Laurentian district, the Adirondack district, the Hastings district, the Original Huronian district, the Lake Superior region, the Great Northern region, Eastern Canada, isolated areas in the Mississippi valley, the Cordilleras, and the eastern United States.

In an appendix on Flow and Fracture of Rocks as Related to Structure, Prof. Hoskins considers the conditions of flow and fracture of rocks, strain and stress, and the applications of the latter to rock structures. As the entire discussion is a summary of a very difficult subject, any attempt to abstract it would probably lead to misconceptions, and, therefore, the attempt is not made.

ART. XXVII.—*Studies upon the Cyperaceæ*; by THEO. HOLM.II. The clado- and antho-prophyllon in the genus *Carex*.  
(With Plate II.)

WHILE the dicotyledonous plants have usually two prophylla developed on their lateral vegetative and floral axes, the monocotyledonous have generally only one. An exception from this rule is, however, the presence of only one in some of the *Dicotyledones*, e. g. *Ranunculus Lingua*, *R. auricomus* and others, while two separate prophylla may occur in some of the *Monocotyledones*, viz.: on the vegetative branches of *Vallisneria*, *Elodea*, etc., or at the inflorescence of *Narcissus*, *Galanthus* and other *Amaryllideæ*.

Besides being the first leaf or leaves upon the lateral branches, the position of the prophyllon is quite characteristic. In the dicotyledonous plants, the two prophylla are situated to the right and the left of the branch, while in the monocotyledonous, the single prophyllon is situated on the posterior side of the branch, thus turning its back towards the mother-axis. As regards the structure of these leaves, they are often more or less scale-like; in the *Monocotyledones* the prophyllon is generally bicarinate with a few, often only two, nerves, which sometimes run out into two tips, hence the leaf appears as if it had developed from two primordia. In most cases, however, this is not so, at least not in the *Gramineæ*, *Cyperaceæ*, *Juncaceæ* and the majority of the *Monocotyledones*, while in the *Amaryllideæ* the so-called spatha is surely formed by coalescence of two separate leaves. This is the more apparent since two flowering branches often develop from these spathæ.

By studying the prophyllon in the genus *Carex*, it is interesting to note the various forms in which it becomes modified in normally developed specimens, while it often undergoes certain transformations, in cases, that are truly abnormal. As the title of this article indicates, we might suggest making a distinction between the prophyllon of the vegetative and of the floral axis, and we might, as a mere matter of convenience, name them according to their place "clado- and antho-prophyllon."

The first of these, the clado-prophyllon, belongs, then, exclusively to the lateral vegetative axes. It is, in the *Cariceæ*, hardly different from the other scale-like leaves of the rhizome, indeed it is generally to be distinguished by its position only, as described above. Since none of the species of *Carex* develop aërial vegetative shoots under normal circumstances,



this leaf becomes confined to the rhizome. There is, however, another leaf in the genus *Carex*, which occupies a somewhat singular position, at the base of the peduncles of the female inflorescences in the heterostachyous species. This leaf was first discovered by Gay, who correctly enough compared it with the utriculus, until later on Roeper succeeded in drawing the comparison still more precise by observing the presence of a female flower in its axil. In this way the leaf becomes a true antho-prophyllon, even if its flower usually stays as a rudiment, or does not develop at all. Very few authors mention this leaf, by Roeper called ochrea or vagina, although its shape varies so much so as to become of some importance in the specific diagnosis. It attains its highest development in species which have long, sheathing stem-leaves, and it has been very comprehensively described by Schulz, who, also, states a number of cases where he found its flower developed. When inclosed by the leaf-sheath it is generally membranous, pale and tubular in its entire length, or but slightly cleft on its anterior face. In species of which the stem-leaves are only clasping, without any distinct sheath, this leaf becomes more scale-like and open, of a firmer texture and often dark brownish, or purplish-colored, and has often several nerves.

The best known antho-prophyllon of the *Carices* is, of course, the so-called utriculus, which surrounds the pistil and is, therefore, exclusively restricted to the female inflorescence. We must admit, though, that mention has been made of a very few instances where this leaf contained stamens, instead of a pistil, as recorded by Boott, in some abnormal specimens of *Carex acuta* L. (Plate II, fig. 7.)

The history of utriculus is most remarkable. There are, indeed, few vegetative organs that have caused greater trouble to the botanists than this leaf, as to its morphological identity. The literature shows us a number of widely opposite theories, suggested by some of the ablest botanists, and it might be of some interest to present a brief outline of the history of this organ, generally known now as the "utriculus." The different names under which it has been described are as follows :

*Achenium*.—(Necker, 1790.)

*Bractææ*.—(R. Brown, 1814.)

*Bractée adossée*.—(Van Tieghem, 1884.)

*Capsula*.—(Tournefort, 1694; Micheli, 1729; Haller, 1742; Schkuhr, 1801; St. Hilaire, Lamarek and DeCandolle, 1805; Schweinitz, 1824.)

*Fruit*.—(Dewey, 1824.)

*Glumes*, two opposite.—(Lindley, 1836.)

*Involucrum*.—(Haller, 1768.)

*Nectarium*.—(Linné, 1791; Wahlenberg, 1803; Nees ab Esenbeck, 1821.)

*Perianthium*.—(R. Brown, 1810; Mirbel and Kunth, 1815; Lestiboudois, 1819. Presl, 1820.)

*Perigynium*.—(Nees ab Esenbeck, 1835; Torrey, 1836; Dyer and McNab, 1875; Bailey, 1889.)

*Phycostemon*.—(Turpin, 1819.)

*Soucoupe*.—(Adanson, 1763.)

*Spathellules*.—(S. Fr. Gray, 1821.)

*Tunica*.—(Ventenat, 1807.)

*Urceolus*.—(DeCandolle, 1813 and 1819; Gaudin, 1811.)

*Utriculus*.—(Scheuchzer, 1719; Kunth, 1837; Roeper, 1844; Richard, 1846; Steudel, 1855; Townsend, 1873; Eichler, 1875; Caruel, 1878; Lindberg, 1885.)

*Vesicula*.—(Tournefort, 1700.)

By comparing these various terms and their definitions, given in the respective works cited, the principal difference seems to consist in whether this leaf should be considered as a part of the flower or as a bract only, a prophyllon. It has been considered as a pericarp, a nectary or disk, a perianth and a perigynium, in contrast to its definition as one or two bracts.

The often bidentate apex might suggest its origin from two primordia, if the history of its development has not taught us different, besides the fact that it never, at least in normal cases, supports more than one single flower. It forms thus a most striking parallel with the palet, the palea superior, of the *Gramineæ*, so excellently discussed by Roeper in his *Flora of Mecklenburg*. We see, also, from the list of its terms, that the name "*utriculus*" is of a very old date, and that it has been adopted in several languages, and there is no reason why it should not be preferred to the rather misleading term "*perigynium*." It is, furthermore, an organ which is absolutely identical with the ochrea described above, and it constitutes together with this the floral or antho-prophyllon of the genus *Carex*.

It is now interesting to observe the transitions which exist between the normal *utriculus* and the ochrea. That the structure of *utriculus* shows a vast number of forms is a fact, which we know from the systematic treatises of our genus. Some abnormal cases might, however, deserve mention. We remember, for instance, that the rhacheola, which bears the *utriculus*, often becomes elongated and bears flowers, especially female ones. It is, in such cases, figured on our Plate II, figs. 2, 4, 5 and 6, that the *utriculus* becomes more or less modified so as to present a development intermediate between that of a typical *utriculus* and of an ochrea, besides that the inflorescence itself may simulate that of *Elyna* or of *Schoenoxiphium*. Such *utriculi*, of which the rhacheola has become

elongated, are, as we know from the literature, very common, although only a few have been, so far, recorded from this country. Penzig, in his *Pflanzeneratologie* (l. c.), enumerates *Carex Fraseri* Andr., *C. intumescens* Rudge, *C. lupulina* — *retrorsa* and *C. utriculata* Boott, as showing this peculiar abnormality, but it is indeed much more common in our American species, especially among the *heterostachya*.

It is upon the elongation of the rhacheola into a long hook, without flowers, that the genus *Uncinia* has been established, while such elongation, but into a straight processus, is perfectly normal to certain true *Carices*, e. g. *C. microglochin* Wahlbg.

The remarkable *Carex cladostachya* Wahlbg., of which we have illustrated a lateral inflorescence (Plate II, fig. 8) shows a very singular ramification, which at first glance may seem to be abnormal, but which, nevertheless, is normal for this species and its allies. Our figure shows a long-peduncled inflorescence, with an ochrea at the base (oc.); there is one terminal, and three lateral inflorescences, which bear female flowers at their bases and male at their apices. These three lateral inflorescences have developed from the axils of scale-like bracts, and their prophyllon, the ochrea, is in this case developed like a typical utriculus with no flower, however (Plate II, fig. 9); it is the rhacheola of this utriculus, or rather ochrea, upon which the female inflorescences and the male flowers are borne.

Hence we have in *C. cladostachya* a species which exhibits a true ochrea, an utriculus and a form intermediate between these.

There are, however, other cases where the utriculus is the only prophyllon of the entire lateral axis. This we have illustrated in *Carex multicaulis* Bailey (Plate II, fig. 10), where the lateral female inflorescences are reduced each to a single flower with its utriculus, and supported by a bract, which here has developed into a green leaf with long blade. The female flower shows here a position corresponding to that, which Roeper had observed inside the ochrea, but this prophyllon has here attained the structure of an utriculus, and the rhacheola has become arrested in its further development.

This species, *C. multicaulis*, belongs to the *Phyllostachya*, which are characterized by their leafy bracts, while in the dioecious *Acroarrhenæ*, the *Physocephalæ* and *Leptocephalæ*, the bracts of the female inflorescences are merely developed as scales. The morphological difference between these groups becomes then confined to the very unimportant fact as to whether the bracts are leaf- or scale-like. The dioecious species of the *Acroarrhenæ* are all known to vary as monoe-



cious, so that the distribution of the sexes does not here constitute any valid character. There is, indeed, no difference, as regards the entire inflorescence, between these, the dioecious forms on the one side and the *Phyllostachyæ*, the *Physocephalæ* and the *Leptocephalæ* on the other; the characterization must be sought in the texture of the utriculus alone. And if we compare them with the heterostachyous species, the principal difference depends merely upon the number of female flowers developed.

It seems as if the homostachyous species, with decomposed inflorescences, form a group well distinct from all the other *Curices*, by the singular arrangement of the two sexes in the same lateral or terminal inflorescence. In these species the lateral peduncles are so short that they are hardly visible and the ochrea is generally suppressed. But if we place *Carex cladostachya* among these, the *Homostachyæ*, we will then have a highly developed type with the inflorescences on long peduncles and the ochrea distinct. This species shows a transition to the *Heterostachyæ* by its decomposed inflorescences, but while this secondary ramification is only abnormal to the heterostachyous species, it is typical to *C. cladostachya* and its allies.

The structure and position of the antho-prophyllon in the genus *Carex* becomes, therefore, of great importance, when we study the inflorescence, and it affords good characters in distinguishing the species from a systematic point of view. In considering the sections and the groups of this large genus, it appears as if the characteristics can not be drawn very acute if we merely look upon the composition of the inflorescence. The characters taken from the structure and shape of the utriculus may, on the other hand, help to unite a number of species into very natural groups. The color of utriculus and of the scale-like bracts is often used as an additional character, but is, however, not reliable. We will point out that the color of these organs often depends upon the climatic conditions under which the species occur, viz.: they are often bright colored, purplish or deep brown, in the northern and the alpine forms, while in the southern and most of the sylvan forms they are pale, hyaline or light green.

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55. Wahlenberg, G. Indledning til Caricographien; Kgl. Sv. Vet. Acad. nya. Hdlgr., vol. xxiv, Stockholm, 1803, p. 74.

## EXPLANATION OF PLATE II.

- FIGURE 1.—The ochrea of a female inflorescence of *Carex crinita* Lam. 3 × natural size.
- FIGURE 2.—A specimen of *Carex laxiflora* Lam. with abnormally developed female inflorescence. The lowest situated stem-leaf has been removed so as to show the ochrea at the base of the peduncle. 2 × natural size.
- FIGURE 3.—The ochrea of the preceding; much enlarged.
- FIGURE 4.—A lateral male spike of *Carex crinita* Lam., which is developed upon the rhacheola of a basal female flower. 3 × natural size.
- FIGURE 5.—A female inflorescence of *Carex longirostris* Torr. with the rhacheola of a flower extended and bearing three female flowers. 3 × natural size.
- FIGURE 6.—A female flower of the preceding, showing a similar prolongation of the rhacheola; much enlarged.
- FIGURE 7.—Two utriculi, with stamens from an abnormally developed specimen of *Carex acuta* L., copied from Boott: Illustr. of the genus *Carex*, vol. iv, p. 166.
- FIGURE 8.—A lateral inflorescence of *Carex cladostachya* Wahlbg., showing the ochrea (oc.) and four lateral inflorescences, female at the base and male at the apex. 2 × natural size.
- FIGURE 9.—One of the basal utriculi of the preceding, from which the lateral inflorescences develop. This utriculus did not contain any female flower, and, as shown in the figure, had the position of an ochrea: at the base of the lateral peduncle; much enlarged.
- FIGURE 10.—The inflorescence of *Carex multicaulis* Bailey, showing one terminal male spike and two lateral female inflorescences, supported by bracts with distinct green blades; much enlarged.

Washington, April, 1896.



ART. XXVIII.—*The Bethany Limestone of the Western Interior Coal Field*; by CHARLES R. KEYES.

THE productive Coal Measures of the Western Interior province, including portions of Iowa, Missouri, Kansas, Arkansas and Indian Territory, are sharply limited at the top by a heavy limestone. Above this level prevail beds which have been laid down in open seas and which have been generally known as the "Upper Coal Measures," or Missourian series. Below are coastal deposits which constitute the coal-bearing Des Moines series.

The limestone which forms the base of the "Upper Coal Measures" was, as an important geological horizon, first brought into prominence in Missouri. Recently it has been found that, although known by different names in the several states, there is every reason to believe that the limestone in question is one of the most persistent horizons in the whole province, and that it forms a well-defined and continuous stratum extending entirely across the basin from west-central Iowa to Indian Territory. In calling attention to the fact a short time ago,\* it was incidentally stated that "the appellation Bethany limestone for the basal formation of the 'Upper Coal Measures' may be extended somewhat, so as to include more than No. 78 of the Broadhead section in Missouri, and may be made to cover several of the limestone beds above the layer to which the term Bethany Falls was originally applied, for the reason that these layers are separated from the main bed only by thin, unimportant seams of shale. Thus it appears that the Winter-set limestone of Iowa and the Erie limestone of Kansas are but extensions of the Bethany limestone of Missouri as now understood; and as the latter was the first to be recognized and to receive a specific geographical name, it has priority and must, therefore, supplant the other terms proposed."

In a late publication† Dr. Erasmus Haworth has taken exception to this statement and has endeavored to show that a name Erie used by him should be applied to the limestone. The question brought up deserves more than passing notice since it raises the query as to what constitutes priority in geological nomenclature, and also since it is of more than local importance. Although the nominal history in this particular instance is not without interest, its consideration has a wide significance as being typical of a large number of cases that have been, and will continue to be, brought up for settlement.

\* This Journal, III. vol. 1, 243, 1895.

† Univ. Geol. Sur. Kansas, vol. i, p. 156, 1896.

There is perhaps no department of geological science that is so backward in its development as that of nomenclature. In botany, in zoology and paleontology there exists a "code" or set of rules by which all questions regarding priority may be readily settled. In geology there is no such fixed standard for guidance. This very problem was forcibly presented by Professor T. McK. Hughes before the British committee on Classification and Nomenclature, at the London meeting of the International Geological Congress,\* and the statement was made that at present "there is no tribunal to which such points can be referred except public opinion." But while there is no special printed "code" to follow, as in other branches of natural history, there are certain general rules which are universally regarded as governing the naming of formations. The first of these is that there must be some definition. There may be differences of opinion as to what constitutes a proper definition, but that the formation to which a name is applied must be defined in some way is everywhere accepted as fundamental in the demands of a term to recognition. Of recent years Prof. H. S. Williams has more clearly formulated the essential elements constituting modern geological definition. These are geological position, geographic distribution and biological definition. It is expected, therefore, that in presenting its claims for a place in nomenclature, no term has grounds for consideration unless it complies in some measure with the requirements with which it is necessary to conform in order to avoid confusion. Although it may not always be explicitly expressed, a formation must have some of the essential characters described in order that it may be again recognized when met with; otherwise its name is meaningless.

In alluding recently to the term Bethany, as having priority over all other names for the basal number of the Missourian series, only the bare fact was stated. The reasons for that conclusion may be now briefly considered in order to show that the objections urged against it, at least in their present form, are not valid. Chronologically arranged, the special references to the limestone in question are as follows:

- 1862. Broadhead, Trans. St. Louis Acad. Sci., vol. ii, pp. 311, 144.
- 1870. White, Geology, Iowa, vol. i, p. 246.
- 1873. Broadhead, Missouri Geol. Sur., Iron Ores and Coal Fields, pt. ii, p. 97, et seq.
- 1894. Haworth and Kirk, Kansas Univ. Quart., vol. ii, p. 108 (January).
- 1894. Keyes, Missouri Geol. Sur., vol. iv, p. 82 (November).
- 1895. Tilton, Iowa Geol. Sur., vol. iii, p. 144 (February).
- 1895. Haworth, Kansas Univ. Quart., vol. iii, p. 275 (April).
- 1895. Keyes, this Journal, III, vol. I, p. 243 (September).
- 1896. Haworth, Univ. Geol. Sur. Kansas, vol. i, p. 159.

\* Cong. géol. international, 4me Sess., 1888, App. B, p. 14, 1891.

Professor Broadhead, in suggesting the name Bethany Falls, originally applied it to the main body of the limestone, the thick massive portion which formed the chief ledge giving the locality its title. Subsequently he defined it clearly, as to geological position and the localities where best exposed. While for the most part the term was confined in its usage to the "main body" of the formation, it was also extended so as to include beds of limestone which were not a part of the main body but which were above it and were separated from it by shales. In the latter part of 1894 it was recognized that the calcareous basal member of the Missourian series properly included, in addition to the main body, the limestone layers both above and below which lay between two heavy shale formations. Although it was desirable to have the formation specifically designated on account of the important position that it held, it was thought unnecessary to propose a new name, when the old one, which was well known, could be made, by slight extensions, to cover the beds in question. Bethany was, therefore, adopted. A few months after the announcement of the application of Bethany to the basal member of the Missourian, Dr. Haworth, who had independently, in Kansas, placed the limestone under consideration at the base of Upper Coal Measures (Missourian), correlated it in part with the Bethany Falls limestone of Broadhead, and designated it as the Erie or Triple limestone. After attention was called incidentally to the fact that it was believed that the term Bethany had priority, Professor Haworth raised several objections to this opinion, which were stated\* as follows:

"Dr. Keyes suggests that inasmuch as this correlation has been perfected, the term Bethany limestone should be applied to the whole group. It is quite evident that Broadhead did not intend his name Bethany to be used in so extensive a sense, and as the term Erie limestone was proposed nearly two years before the suggestion made by Doctor Keyes, priority would not allow the use of the term as he suggests." Two questions arise in this connection: (1) whether the original usage of the term Bethany Falls can be, with propriety, extended; and (2) if not, can Erie be regarded as defined prior to the extension of the term Bethany as used in the recent Missouri geological report.

Regarding the first problem, there can be no doubt that the formation is sufficiently well defined to have its name retained for the main body of the limestone, if that should be desirable. Moreover, in this sense it was applied not to the lowermost bed, as stated by Dr. Haworth, but to more of a median section of the limestone formation. At the same time it included more

\* Univ. Geol. Sur. Kansas, vol. i, p. 156, 1896.



strata than are embraced in the "main body." Therefore there does not appear, especially in the light of later investigation and a consequent desirability to adjust the nomenclature without the introduction of any more new terms than is absolutely necessary, to be any impropriety in extending somewhat the original meaning of the title. There is no violation of universal custom, no confusion incurred.

Regarding the term Erie itself, Dr. Haworth claims that it has priority over Bethany because it was "proposed" previous to the formal extension of the latter term to the whole of the basal limestone formations. By referring back to the places cited, in which the term Erie is used, it is found that the first time that it was mentioned, according to the references made by Dr. Haworth, was in a preliminary description of a section made up the Neosho river in southeastern Kansas. It is reported as sixty feet thick and as occurring at several localities. "It may be called the Erie limestone on account of its greater abundance in the neighborhood of that thrifty little town." Nothing is given of its biological characters, nothing of its geological position, except that it is somewhere in the Coal Measures, and lies between the "Laneville" shales and the "Chanute" shales.

In another account, which appeared a year later, but a few months after the formal extension of the term Bethany over the whole of the limestone formation, Dr. Haworth again considers the member in question. It is now described fully as the "Triple" limestone, with only an incidental reference in another place to "Erie." The names of the underlying and overlying shales are changed also, to "Pleasanton" and "Thayer." The geological position of the formation, however, is accurately located at the base of the Upper Coal Measures and the lowermost bed of the "Triple" limestone is correlated with the Bethany Falls limestone, the latter being erroneously regarded as the basal part of the limestone formation. From this it is evident that in the first usage of the name, "Erie" cannot be regarded as defined, and it must be also concluded that Dr. Haworth, in his preliminary description of the Neosho river section, did not even have in mind the formal proposition of the term Erie for a widespread geological formation.

There is still another consideration in this connection that demands attention. If in any way the first usage of the term "Erie" can be regarded as a proper definition of the formation and the title can be in any manner considered as having priority over Bethany, then the term Winterset, as suggested by Dr. White for apparently the same formation in Iowa, has precedence. Dr. White makes frequent mention in his Iowa reports of

the "Winterset section," the "limestone of the Winterset section," the "Winterset stone," etc. The formation was admirably defined, a good detailed section was given, its geological position was accurately located, its typical locality was given and its faunal characteristics were described. The section itself has long been the standard of comparison for the "Upper Coal Measures" of Iowa. If Bethany cannot be considered as a valid title for the basal limestone of the "Upper Coal Measures," or Missourian series, as now understood, it is manifest that Erie cannot be, but must give way to Winterset.

For these reasons it was that Bethany was given priority\* as the proper name of the important limestone at the bottom of the "Upper Coal Measures" in the Western Interior province, as a valid title unusually well defined for its time, widely known and liable to occasion the least amount of confusion in geological nomenclature.

Thus far nothing has been said regarding the name Erie as a title already preoccupied in geological literature. The term has been used a number of times. Bela Hubbard,† assistant geologist to the first Geological Survey of Michigan under Houghton, described in 1841 the "limestones of Lake Erie." In 1842 the New York geologists Emmons‡ and Vanuxem,§ and the year following Hall|| and Mather¶ described fully the "Erie division" of the Devonian. Winchell\*\* also recognized the Erie limestones of Houghton. In 1873, Newberry†† proposed the term Erie shale for the uppermost formation of the Devonian of Ohio; and the following year‡‡ he recognized the Erie clays of the Quaternary, which is the same name which Logan had some years previous applied to the formations on the north shore of Lake Erie.

\* This Journal, III, vol. 1, pp. 239-243, 1895.

† Fourth Ann. Rept. State Geologist. Report No. 3, 1841.

‡ Final Rept. Second Dist. New York, p. 429, 1842.

§ Final Rept. Third Dist. New York, p. 13, 1842.

|| Final Rept. Fourth Dist. New York, p. 19, 1843.

¶ Final Rept. First Dist. New York, p. 2, 1843.

\*\* Geol. Sur. Michigan, 1st Bienn. Rept., pp. 12-15, 1861.

†† Geol. Sur. Ohio, vol. i, p. 163, 1873.

‡‡ Geol. Sur. Ohio, vol. ii, p. 21, 1874.

ART. XXIX.—*On the Surface Tension of Mixtures of Normal Liquids*; by C. E. LINEBARGER.

IN the ingenious method of estimating between certain limits of temperature the molecular mass of a liquid devised by Ramsay and Shields,\* it is assumed that the various kinds of molecules that may occur in a liquid are uniformly distributed throughout the entire body of the liquid so that no one kind predominates in its surface. That such an assumption is in accordance with the facts of the case has been proven by Ramsay and Aston,† who determined the superficial tensions and energies of several mixtures of liquids that do not undergo appreciable polymerization. While in some instances they found that the molecular surface energies of mixtures were the mean of the molecular surface energies of their component liquids, yet in others such was not the case.

The object of this paper is to add to our knowledge of the relations of the capillary constants of normal liquids and their mixtures. The determinations of this physical property were made with the apparatus described in a previous article in this Journal, p. 110. The liquids employed were of a high grade of purity and the composition of their mixtures was determined with the greatest care.

The following tables give the data obtained, the headings to each of which render any explanation here needless, except, perhaps, for the last column, where the minus sign before a number indicates that the observed surface tension is greater than the calculated, and the plus sign the opposite. The surface tensions are given in dynes per centimeter.

TABLE I.  
*Surface Tension of Mixtures of Benzene and Toluene.*

| Percentage Composition. |          | Molecular Percentage Composition. |          | Specific Gravity. | Temperature 25.°0         |                             | Differences. |
|-------------------------|----------|-----------------------------------|----------|-------------------|---------------------------|-----------------------------|--------------|
| $C_6H_6$                | $C_7H_8$ | $C_6H_6$                          | $C_7H_8$ |                   | Observed Surface Tension. | Calculated Surface Tension. |              |
| 0.000                   | 100.000  | 0.000                             | 100.000  | 0.85680           | 26.74                     |                             |              |
| 30.588                  | 69.412   | 34.230                            | 65.770   | 0.86635           | 27.00                     | 26.91                       | —0.09        |
| 66.576                  | 33.424   | 70.240                            | 29.760   | 0.87143           | 27.19                     | 27.13                       | —0.06        |
| 90.720                  | 9.280    | 92.011                            | 7.989    | 0.87366           | 27.28                     | 27.24                       | —0.04        |
| 91.556                  | 8.444    | 92.750                            | 7.250    | 0.87528           | 27.27                     | 27.24                       | —0.03        |
| 100.000                 | 0.000    | 100.000                           | 0.000    | 0.87661           |                           | 27.29                       |              |

\* Zeitschr. f. phys. Chem., xii, p. 433, 1893.

† Ibid., xv, p. 89, 1894.



TABLE II.

*Surface Tension of Mixtures of Toluene and Turpentine.*

| Percentage Composition. |                | Molecular Percentage Composition. |                | Specific Gravity. | Temperature 25°.0         |                             | Differences. |
|-------------------------|----------------|-----------------------------------|----------------|-------------------|---------------------------|-----------------------------|--------------|
| $C_7H_8$                | $C_{10}H_{16}$ | $C_7H_8$                          | $C_{10}H_{16}$ |                   | Observed Surface Tension. | Calculated Surface Tension. |              |
| 0.000                   | 100.000        | 0.000                             | 100.000        | 0.85790           | 25.93                     |                             |              |
| 6.791                   | 93.209         | 9.724                             | 90.276         | 0.85960           | 25.98                     | 25.99                       | +0.01        |
| 20.654                  | 79.346         | 27.464                            | 72.536         | 0.85838           | 26.08                     | 26.11                       | +0.03        |
| 53.701                  | 46.299         | 63.162                            | 36.838         | 0.85682           | 26.18                     | 26.31                       | +0.13        |
| 75.091                  | 24.909         | 89.884                            | 20.116         | 0.85654           | 26.25                     | 26.54                       | +0.29        |
| 100.000                 | 0.000          | 100.000                           | 0.000          | 0.85680           | 26.74                     |                             |              |

TABLE III.

*Surface Tension of Mixtures of Benzene and Ethyl Oxide.*

| Percentage Composition. |              | Molecular Percentage Composition. |              | Specific Gravity. | Temperature 25°.0         |                             | Differences. |
|-------------------------|--------------|-----------------------------------|--------------|-------------------|---------------------------|-----------------------------|--------------|
| $C_6H_6$                | $C_4H_{10}O$ | $C_6H_6$                          | $C_4H_{10}O$ |                   | Observed Surface Tension. | Calculated Surface Tension. |              |
| 0.000                   | 100.000      | 0.000                             | 100.000      | 0.70942           | 16.35                     |                             |              |
| 28.576                  | 71.424       | 27.502                            | 72.498       | 0.75369           | 17.62                     | 19.45                       | +1.83        |
| 56.924                  | 43.076       | 55.627                            | 44.373       | 0.79972           | 21.02                     | 22.53                       | +1.51        |
| 54.691                  | 24.309       | 74.709                            | 25.291       | 0.83179           | 23.44                     | 24.57                       | +1.13        |
| 100.000                 | 0.000        | 100.000                           | 0.000        | 0.87390           | 27.29                     |                             |              |

TABLE IV.

*Surface Tension of Mixtures of Toluene and Carbon Bisulphide.*

| Percentage Composition. |         | Molecular Percentage Composition. |         | Specific Gravity. | Temperature 25°.0         |                             | Differences. |
|-------------------------|---------|-----------------------------------|---------|-------------------|---------------------------|-----------------------------|--------------|
| $C_7H_8$                | $CS_2$  | $C_7H_8$                          | $CS_2$  |                   | Observed Surface Tension. | Calculated Surface Tension. |              |
| 0.000                   | 100.000 | 0.000                             | 100.000 | 1.25958           | 31.29                     |                             |              |
| 7.269                   | 92.731  | 6.082                             | 93.918  | 1.21783           | 30.83                     | 30.96                       | +0.13        |
| 37.992                  | 62.008  | 33.605                            | 66.395  | 1.06759           | 29.15                     | 29.56                       | +0.41        |
| 63.242                  | 36.758  | 58.699                            | 41.301  | 0.97217           | 27.95                     | 28.41                       | +0.46        |
| 100.000                 | 0.000   | 100.000                           | 0.000   | 0.85680           | 26.74                     |                             |              |

TABLE V.

*Surface Tension of Mixtures of Toluene and Ethyl Benzoate.*

| Percentage Composition. |                | Molecular Percentage Composition. |                | Specific Gravity. | Temperature 25°.0         |                             | Differences. |
|-------------------------|----------------|-----------------------------------|----------------|-------------------|---------------------------|-----------------------------|--------------|
| $C_7H_8$                | $C_9H_{10}O_2$ | $C_7H_8$                          | $C_9H_{10}O_2$ |                   | Observed Surface Tension. | Calculated Surface Tension. |              |
| 0.000                   | 100.000        | 0.000                             | 100.000        | 1.04843           | 34.07                     |                             |              |
| 15.282                  | 84.718         | 22.726                            | 77.274         | 1.01458           | 32.44                     | 32.94                       | +0.50        |
| 47.322                  | 52.678         | 59.450                            | 40.550         | 0.94937           | 29.34                     | 30.60                       | +1.26        |
| 76.170                  | 23.830         | 83.918                            | 16.082         | 0.89667           | 27.94                     | 28.49                       | +0.55        |
| 100.000                 | 0.000          | 100.000                           | 0.000          | 0.85680           | 26.74                     |                             |              |

TABLE VI.

*Surface Tension of Mixtures of Ethyl Oxide and Ethyl Iodide.*

| Percentage Composition. |           | Molecular Percentage Composition. |           | Specific Gravity. | Temperature 25° C         |                             | Differences. |
|-------------------------|-----------|-----------------------------------|-----------|-------------------|---------------------------|-----------------------------|--------------|
| $C_4H_{10}O$            | $C_2H_5I$ | $C_4H_{10}O$                      | $C_2H_5I$ |                   | Observed Surface Tension. | Calculated Surface Tension. |              |
| 0.000                   | 100.000   | 0.000                             | 100.000   | 1.93012           | 29.49                     |                             |              |
| 37.200                  | 62.800    | 55.581                            | 44.419    | 1.17996           | 20.57                     | 19.13                       | -1.44        |
| 100.000                 | 0.000     | 100.000                           | 0.000     | 0.70942           | 16.35                     |                             |              |

TABLE VII.

*Surface Tension of Mixtures of Ethyl Oxide and Carbon Bisulphide.*

| Percentage Composition. |         | Molecular Percentage Composition. |         | Specific Gravity. | Temperature 25° C         |                             | Differences. |
|-------------------------|---------|-----------------------------------|---------|-------------------|---------------------------|-----------------------------|--------------|
| $C_4H_{10}O$            | $CS_2$  | $C_4H_{10}O$                      | $CS_2$  |                   | Observed Surface Tension. | Calculated Surface Tension. |              |
| 0.000                   | 100.000 | 0.000                             | 100.000 | 1.25958           | 31.29                     |                             |              |
| 13.100                  | 86.900  | 13.407                            | 86.593  | 1.14280           | 26.19                     | 29.61                       | +3.42        |
| 34.367                  | 65.633  | 34.969                            | 65.031  | 0.99380           | 21.86                     | 26.16                       | +4.30        |
| 62.759                  | 37.241  | 63.380                            | 36.620  | 0.84699           | 18.65                     | 21.91                       | +3.26        |
| 100.000                 | 0.000   | 100.000                           | 0.000   | 0.70942           | 16.35                     |                             |              |

The results communicated in the foregoing tables show that in the majority of cases the superficial tensions of mixtures of normal liquids are not calculable by the rule of mixtures from the superficial tensions of the pure liquids. Mixtures of benzene and toluene show differences between the calculated and observed values of their surface tensions that are less than those attributable to experimental errors. Yet it must be borne in mind that the method of determination does not yield results that are accurate on an average to more than one part in a thousand, and it is quite permissible to believe that more accurate experimental methods will show marked differences between the calculated and observed values of the physical constant under discussion.

It is to be observed that there are no abrupt changes in the capillary constants of any of the mixtures, that is to say, if the observed value is greater or less than the calculated value for any one mixture of two liquids, it is also greater or less for any other mixture of the same two liquids; the signs before the numbers in the column marked "Differences" remains the same for every series of mixtures.

ART. XXX.—*Thickness of the Paleozoic Sediments in Arkansas*; by JOHN C. BRANNER. With a Map (Plate III).

THE general divisions of the rocks of Arkansas are shown on the accompanying geological map. There are no Archæan rocks in the state, and the bottom of the Paleozoic beds is, therefore, not exposed. The syenites of the state, formerly supposed to be Archæan, are eruptives, probably of Tertiary age; whether the "red granite" said to occur at the mouth of Spavina Creek in the Indian Territory, near the northwest corner of the state,\* is Archæan, is not known at present.

The total thickness of the oldest sediments cannot, therefore, be determined from direct observations within the state, and the total given in the present paper is, for that region, less than it should be.

On the other hand, the method of giving maximum thicknesses and of obtaining the total thickness of any one series of beds by adding together outcrops observed at many different localities, is liable to give an exaggerated idea of the total thickness of sediments, for in all probability no such total exists at any one place.

The lowest rocks—the Lower Silurian—are exposed in Arkansas in two separate regions: the first in the region of the Ouachita uplifts, running west from Little Rock past Mt. Ida to the Indian Territory; the second north of the Boston Mountains along the Missouri line.

In the former area the rocks are exposed by erosion in a region of sharp folds; in the latter they are horizontal or nearly so, are faulted in a few places, and are exposed for the most part by the trenching of the streams and the exposure of perpendicular bluffs, where the character and thickness of the beds may readily be inspected.

In the region of the Ouachita uplift no attempt has been made to subdivide the Silurian beds, further than to locate the novaculites. Very few fossils have ever been found in this area and no correlation of the rocks with those of other Silurian area of the state is possible at present, further than that made by Dr. R. R. Gurley, based upon a study of the graptolites found there. He says that a Trenton horizon and a Calceiferous horizon are represented.† Mr. Griswold, who has studied this area more thoroughly than any one else, says that the shales, limestones, and quartzose sandstones below the novaculite have a thickness of about 1300 feet, while the

\* Second report of a geological reconnaissance of Arkansas, by D. D. Owen, Philadelphia, 1860, pp. 17 and 408.

† Ann. Rep. Geol. Surv. Ark. for 1890, vol. iii, p. 401.



novaculites are about 1260 feet thick, making a total thickness of 2560 feet of Silurian sediment exposed in the Ouachita uplift.\*

The lower Carboniferous beds are not represented, so far as we know, in the Ouachita uplift, but the Lower Coal Measures (Pennsylvanian) rocks seem to rest directly upon the Silurian novaculites.

In the Silurian area north of the Boston Mountains the rocks are sandstones, cherts, magnesian limestones and a few beds of shale. The lowest rocks in the Boston Mountain region of which we have any knowledge are those penetrated by the deep well bored near Cushman, Independence County. This well gives a thickness of 1750 feet below the Izard limestone.†

Overlying this unclassified (in Arkansas) group of sediments is a bed I have called the Izard limestone, from its development in the southeastern part of Izard county; according to Penrose this limestone has a maximum thickness of 285 feet‡ at Penter's Bluff on the White River. From the manganese region in Independence and Izard counties it thins out east, west, north and south.

Next above the Izard limestone is the St. Clair marble with a maximum thickness of 155 feet at Penter's Bluff; it also thins out on all sides and is not known in the western part of the state.

According to Dr. H. S. Williams, who has carefully studied the paleontology of these rocks, the lower part of the St. Clair bed of Penrose is "about equivalent to that of the Nashville group of Tennessee or the Cincinnati group of Ohio,"§ while the upper part of it contains fossils "equivalent to the Waldron fauna of Indiana or to the Clinton-Niagara fauna of New York," and the middle is of "early Niagara." The last two divisions are Upper Silurian.

Next above the St. Clair marble is what I have called the Eureka shale with a maximum thickness in Washington County of 50 feet.|| The age of this shale has not been definitely settled. In Tennessee, Safford calls it the "Black shale" and refers it provisionally to the Devonian; Hershey thinks it is the equivalent of shales of Devonian age in Iowa and Illinois.¶

\* Ann. Rep. Geol. Survey of Ark., for 1890, p. 206, and plate III, p. 209.

† Op. cit., vol. i, Manganese, by R. A. F. Penrose, Jr., pp. 117-118.

‡ Annual report of the Geol. Survey of Ark. for 1890, vol. i, Manganese, by R. A. F. Penrose, Jr., Little Rock, 1891, pp. 121-122. Also marbles and other limestones, vol. iv, by T. C. Hopkins, p. 108.

§ On the age of the Manganese beds of the Batesville region of Arkansas, by Henry S. Williams, this Journal, III, 1894, xlviii, 326.

|| Ann. Rep. Geol. Survey of Ark. for 1888, vol. iv, Washington County, p. xiii.

¶ The Devonian series in southwestern Missouri, by Oscar H. Hershey, Amer. Geologist, 1895, xvi, 294-300.

The fossils found in the Eureka shale in Arkansas are mostly *Discinas* and *Lingulas* and are of but little use in correlation, but inasmuch as crinoid stems are abundant in places, and as the shale merges gradually into the overlying Carboniferous limestones, I am inclined to believe that it belongs with the Carboniferous rocks.

The Sylamore sandstone (one of the phosphate beds of Arkansas) has a maximum thickness of 40 feet on Sylamore Creek in Stone County; it sometimes replaces the Eureka shale; often it is entirely wanting. At St. Joe a thin bed (4') overlies the shale, and a thicker one (2-4 feet) underlies it.\*

Thus far but few recognizable fossils have been found in this formation.

Above the Sylamore sandstone and Eureka shale is the chert-bearing limestones (sometimes containing sandstones also) which I have called the Boone chert on account of its wide occurrence and development in Boone County. It is found throughout the entire Paleozoic area of North Arkansas north of the Boston Mountains, and has a maximum thickness of 370 feet.

The next horizon, named by Prof. F. W. Simonds the "Wyman sandstone," has a thickness of only 10 feet.† Above it the Fayetteville shale (Simonds), a widespread formation north of the Boston Mountains, has a maximum thickness of 300 feet near Batesville.

Next, the Batesville sandstone has a thickness of 200 feet in the western part of the state. The Batesville sandstone lies at the top of the Arkansas equivalent of the Keokuk and Burlington. Then follows what I have called the Boston group, a series of shales, sandstones and limestones, which form the upper portion of the Lower Carboniferous or Mississippian: these taken together have a maximum thickness of 780 feet. This brings the section to the base of the Coal Measures or Pennsylvanian.

In the Boston Mountain region the lowest member of the Pennsylvanian series, the Millstone Grit, has a thickness, in places, of 500 feet.‡ With the exception of some of the sandstones and shales that have been extensively eroded in that region, this is the highest member of the series exposed along the north side of the Boston Mountains, and the remainder of the group must therefore be measured in the Arkansas Valley.

\* In Tennessee, Safford reports a similar sandstone below the shale (Geology of Tenn., p. 330); Meadows and Brown speak of it both above and below (Trans. Am. Inst. M. E., xxiv, 189, 585, 589); Hayes represents it as below (Sixteenth Ann. Rep. U. S. G. S., pt. iv, pl. vi).

† Ann. Rep. Geol. Surv. of Ark. for 1891, vol. iv; Geology of Benton County, by F. W. Simonds and T. C. Hopkins, p. 27.

‡ Ann. Rep. Geol. Surv. of Ark., 1888, vol. iv, p. 137; 1890, vol. i, p. 140.

Beginning at the base of the Lower Coal Measures rocks southwest of Little Rock where they rest directly upon the Silurian novaculites, and going across the strike, nearly due north, to the Big Rock syncline whose axis crosses the Arkansas River two miles above Little Rock, we have a series of sandstones and clay shales, the latter predominating. The rocks all have very steep, almost vertical north dips except near the axis of the syncline; this belt is from three to four and a half miles wide. If they are not faulted or overturned, these beds have a thickness of something more than 16,000 feet. It is not improbable that they are faulted, however, for they are mostly clay shales, with an abundance of large quartz veins, and the beds exposed at the "little rock" on the river bank at Little Rock are much crushed and distorted; faulting in this case must have tended to conceal a part of the true thickness of the rocks.

About four and a half miles north of the Big Rock axis is another syncline whose uppermost beds are at about the same horizon as those at Big Rock. The same beds are again exposed in a third syncline—the Cato syncline—fourteen miles north of Little Rock. The Cato synclinal axis is shown on the accompanying plate (p. 233). It lies east-west, and at its western extremity turns northward and ends in the Round Mountain. The rocks exposed at the axis of this syncline are at or very near the same horizon as those at the axis of the Big Rock syncline, so that we are here apparently no higher geologically than at Big Rock. Fortunately the geology hereabout and especially from Cato north to the Bayou Meto anticline, west to Round Mountain and thence to the Cadron anticline, north of Conway, is so plain that there can be no serious doubt about the thickness calculated for the several beds. An examination of the accompanying figure will, I believe, make this evident.\*

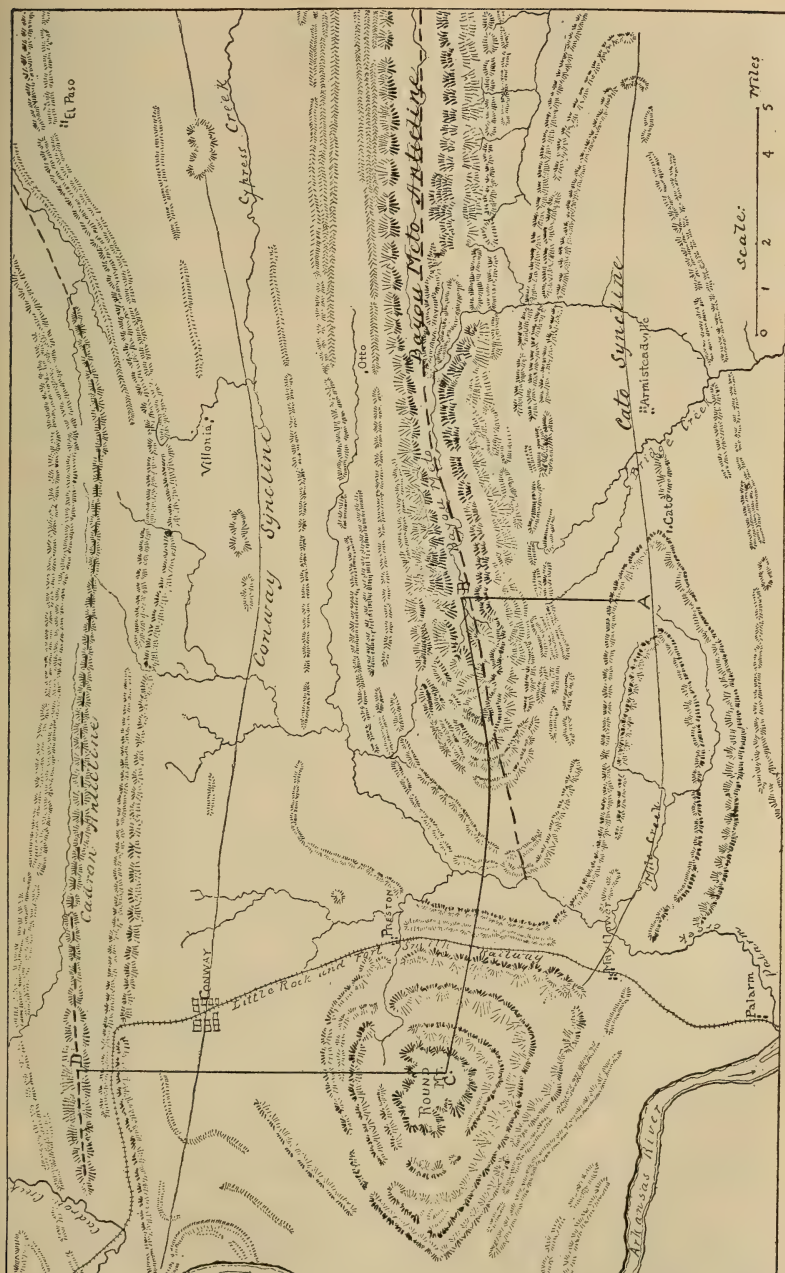
The rocks are alternate beds of sandstone and shale, and erosion has developed a striking system of sandstone ridges and shale valleys: in some places these valleys and ridges may be traced for fifty miles, doubling back and forth upon themselves. The directions and continuity of the many sandstone ridges show that there can be no considerable faults or overturns.

From the top rocks of the Cato syncline (A on map, p. 233) to the bottom rocks of the Bayou Meto anticline (B on map) the rocks exposed have a total thickness of 14,900 feet.

But the top of the syncline at the starting point has been

\* The details of the geology in the region represented on the figure were worked out by Mr. John H. Means and the figure was taken from his valuable map. Mr. Means has prepared a report upon the Lower Coal Measures area of Arkansas, but thus far the State has not published it.





removed by erosion. If one turns nearly due east, from the Bayou Meto anticline, crosses the Little Rock and Fort Smith railway a mile or two south of Preston, and goes to the top of Round Mountain in 4 N. 14 W. (C on the map), he will cross over the same series of rocks, plus the beds forming Round Mountain. All the way the dip is toward the west, and the total thickness of the exposed rocks is 18,480 feet.

Another series of observations made along a line run north from the top of Round Mountain to the axis of an anticline three miles north of Conway (D on the map), and deducting for the gentle fold near Conway, gives a thickness of 17,730 feet.

I lay particular stress upon these three measurements because they involve the greater part of the thickness of the Lower Coal Measures rocks, and because, judging from the manner in which these three sections agree, there seems to be no possibility of any serious mistake in estimating their thickness.

It ought to be noted here that in 1889 I authorized Mr. Griswold to say that the rocks of the Coal Measures in Arkansas had a total thickness of four miles.\* This statement was based upon a section examined and measured between the Petit Jean Mountain and the Silurian novaculites of the Ouachita uplift. But there was no certainty that the rocks along this section were not repeated by folds or faults, and the thickness seemed so unusual that I afterwards sent assistant J. F. Newsom (now Professor of Geology in the University of Indiana) over another part of the same beds with a view to checking my results. The three measurements here given from the Cato syncline to the Bayou Meto anticline, thence to Round Mountain, and from Round Mountain to the Cadron anticline, are the results of Professor Newsom's work.†

So far as I can make out, the sandstones in the top of Round Mountain are at the same geological horizon as those in the tops of Carrion Crow Mountain, Petit Jean Mountain and Mount Nebo, and these sandstones lie only a short distance below the Ouita coal bed near Russellville.

From the base of the productive Coal Measures (beginning at the top of Carrion Crow Mountain) to the top of the Poteau Mountain at the Indian Territory line, there is a maximum thickness of 5300 feet, of which 3500 feet belong to the upper series, which Mr. Winslow proposes to call the Poteau group.

\* Ann. Rep. Geol. Sur. for 1890, vol. iii, Whetstones and the Novaculites of Ark.; by L. S. Griswold, p. 206.

† In his report to me Professor Newsom notes the fact that the measurement on the south side of Bayou Meto anticline gives a thickness of 14,900 feet, and that the measurement on the west side, or down its nose to the ridge corresponding to that at the synclinal trough on the south, gives 14,520 feet—a difference of only 380 feet.

In the Lower Coal Measures area lying south of the Ouachita uplift Dr. George H. Ashley, who worked out the details of the geology of that region, found 5200 feet of sediments above the Silurian on West Saline River, and on the Rolling Fork of Little River he found 6800 feet, with the bottom still concealed.

These sediments are overlapped by the Cretaceous rocks to the south, so that the total thickness of the beds on that side of the Ouachita uplift is not visible.

*Table of Thickness of the Paleozoic Sediments of Arkansas.*

|  |   | Bost.<br>Mts.<br>feet.   | Ark.<br>Valley.<br>feet.   |
|--|---|--------------------------|----------------------------|
| Coal Measures<br>or<br>Pennsylvanian         | { | Upper Coal M.            | { Poteau beds..... 3500    |
|  |   |                          | { Productive beds .. 1800  |
|  |   | Lower Coal M.            | Barren beds ..... 18480    |
|  |   | "Millstone grit" .....   | 500                        |
| Lower<br>Carboni-<br>ferous or               | { | "Chester, St. Louis"     | { Bost. group.... 780      |
|  |   | "Warsaw"                 |                            |
| Missis-<br>sippian.                          | { | "Keokuk"                 | Batesville sandstone.. 200 |
|  |   |                          | "Burlington"               |
|  |   | Wyman sandstone .. 10    |                            |
|  |   | Boone chert..... 370     |                            |
| Devonian(?).....                             | { | Sylamore sandstone.. 40  |                            |
|  |   | Eureka shale..... 50     |                            |
| Upper Silurian.....                          | { | St. Clair Marble.... 155 |                            |
| Lower Silurian.....                          | { | Izard limestone..... 285 |                            |
|  |   | Underlying beds ... 1750 |                            |
|  |   | +                        | +                          |
|  |   | 4440                     | 23,780 +                   |
| Total thickness of known Paleozoic sediments |   | 28,220 feet.             |                            |

There is, of course, nothing remarkable about the thickness of any of the Arkansas sediments except in the case of the Lower Coal Measures. So far as I can learn, the thickness of the Carboniferous rocks in this section is greater than that of sediments of the same age in other parts of the country or of the world.

Hitherto the Carboniferous sediments of Nova Scotia have been looked upon as the thickest on the Continent—between 10,000 and 16,000 feet.\*

\* There has been some disagreement about the thickness of these beds. Sir Wm. Logan reported 14,570 feet; later Sir Wm. Dawson gave 10,000 feet for the Coal Measures proper (Proc. Am. Phil. Soc. 1862, ix, 101; 1863, ix, 208;



In the Wahsatch section of Utah and Eastern Nevada the Weber quartzite and its overlying Coal Measures and Permian beds have a thickness of 10,650 and possibly of 16,650 feet.\*

In the Indian Territory Chance reports a thickness of 8500 to 10,000 feet in the Carboniferous rocks, but that is simply another part of the Arkansas valley basin.†

*Thickness of Coal Measures (Pennsylvanian) Sediments in North America.*

|                        |            |
|------------------------|------------|
| Arkansas .....         | 23,780     |
| Nova Scotia .....      | 16,000     |
| Utah and Nevada .....  | 16,650 (?) |
| Indian Territory ..... | 10,000     |

In other parts of the Mississippi basin containing Coal Measures rocks the beds are generally less than 5000 feet thick, the thicker portions lying along the eastern border of the Appalachian coal fields from Pennsylvania to Alabama, where they are 5500 feet thick.

If we inquire into the reason for the great thickness of Coal Measures sediment in the Arkansas Valley, I believe it is to be found in the drainage of the continent during Carboniferous times. The rocks of this series in Arkansas contain occasional marine fossils, and these marine beds alternate with brackish or freshwater beds whose fossils are mostly ferns and such like land or marsh plants. This part of the continent was, therefore, probably not much above tide level. The drainage from near the Catskill Mountains in New York flowed south and west. The eastern limit of the basin was somewhere near the Archæan belt extending from New England to Central Alabama. This Appalachian watershed crossed the present channel of the Mississippi from Central Alabama to the Ouachita uplift, or to a watershed still farther south and now entirely obliterated and buried in Northern Louisiana. In any case the drainage flowed westward through what is now the Arkansas valley between the Ozark Island on the north and the Arkansas Island on the south.

Acadian Geology, 2d ed., 1868, 149, 146, and 151), and still later 14,000 and 16,000 feet (Quar. Jour. Geol. Soc., xxx, 210). Mr. Gilpin says that H. Fletcher of the Canadian Survey gives a total thickness of 21,960 feet for all the Carboniferous of Cape Breton. This, however, includes the Lower Carboniferous (Quar. Jour. Geol. Soc., xlii, 1886, p. 524).

\* U. S. Geol. Expl. 40th Parallel, I, Systematic Geology, by Clarence King, pp 240, 248.

† Trans. Amer. Inst. Mining Engineers, 1889-90, xviii, p. 655.

ART. XXXI.—*The Devonian of North Missouri, with notice of a new fossil*; by G. C. BROADHEAD.

THERE is probably not over fifty feet thickness of the Devonian in North Missouri where it is chiefly exposed in the counties of Lincoln, Pike, Ralls and Callaway. In Pike and Ralls the upper portion consists of a few feet of black shales at top with limestone beds below. The fossils contained are chiefly *Atrypa reticularis*, *A. aspera*, *Spirifer eruteines* and a few corals. Westwardly in Warren and Montgomery the Devonian is inconspicuous. In Callaway it is better developed and in several neighborhoods fossils are abundant, the most prominent being *Atrypa reticularis*, *A. affinis*, *Cyrtia* —, several species of *Strophodonta*, *Orthis iowensis*, *Stromatopora*, *Zaphrentis gigantea*, *Favosites* several species, and several species of Cephalopoda.

At Providence, Boone County, about 25 feet of Devonian limestone is exposed containing a few rare and interesting fossils, including *Spirifer eruteines*, *Favosites alpenensis* and *Stromatopora expansa*, and four feet below the top we find *Loxonema robusta*, *Murchisonia* and an interesting gasteropod not heretofore found in Missouri and not described. The following is a description of it.

*Pleurotomaria Providencis.*

Shell subglobose, depressed, spire moderately elevated, apex apparently eroded. Volutions three or four, the last whorl much expanded. Aperture circular. Surface marked by numerous striæ or lines of growth which are occasionally imbricated, strongly marked and unevenly fasciculated.

A sulcus one-tenth of an inch broad and about one-half as deep divides the upper and lower part of each whorl. The striæ as they pass from the suture curve backwards, increasing in curvature as they approach the medial sulcus, where they are so much crowded as to form a low border to the sulcus. In crossing the sulcus they are concave in front. On the lower side of the sulcus they also curve backward and form a sharp border to the sulcus similar to that formed above.

In average-sized specimens there is a row of prominent nodes about half way between the sulcus and the suture. These nodes at their upper and lower portions are elongated into a low ridge which follows the direction of the lines of growth of the shell, but is soon blended into the body whorl. There is also another range of nodes below the sulcus and some-

times a faint appearance of a second row. The shell also presents a somewhat nodular appearance just below the suture. The suture is well defined.

The lower side of the last volution is regularly curved, the upper side more often rough-looking from the presence of nodes and the occasional prominence of the lines of growth.

On the last volution of old shells the nodes almost disappear but the sulcus continues to be well marked. Columellar lip thick, flattened, making an angle of about  $80^\circ$  with the outer surface of the shell.

|                                    |          |
|------------------------------------|----------|
| Height of an average specimen..... | 2 inches |
| Breadth " " ".....                 | 2 inches |

Some shells are one-half larger.

This shell in general form resembles *Turbo shumardi* of De Verneuil, but the latter is crossed with swollen ridges instead of nodes and they cross the lines of growth instead of following them. The *T. Shumardi* also has no sulcus. The sulcus in our shell seems to be a filled slit and, therefore, we have placed it in the genus *Pleurotomaria*.

Columbia, Mo., June 11, 1896.

FIGURE 1.—Average specimen.

FIGURE 2.—Under side of last whorl showing umbilical region.

FIGURE 3.—Part of an old shell showing ornamentation on last whorl.

FIGURE 4.—Vertical section.

FIGURE 5.—Part of whorl showing nodes with sulcus between.

FIGURE 6.—Part of an old shell crushed.

FIGURE 7.—Section across back of whorl showing sulcus and elevation of ridges and nodes.

All of natural size.



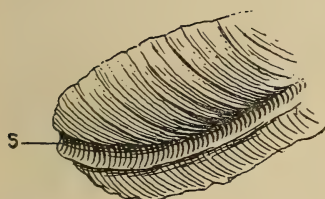
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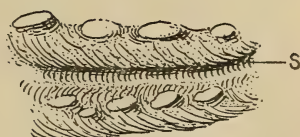
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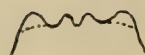
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ART. XXXII.—*A Visit to the Great Barrier Reef of Australia,\** by A. AGASSIZ.

\* Extract from a letter to the editor dated Cook Town, Queensland, May 16th, 1896.

. . . . . THE steamer "Croydon" of the A. U. S. N. Co. was chartered for my exploration of the Great Barrier Reef. Dr. W. McM. Woodworth and Mr. A. G. Mayer accompanied me as assistants. We carried a complete photographic apparatus and an extensive outfit for pelagic fishing in the way of surface as well as of deep sea Tanner nets, with the usual apparatus for sounding in moderate depths. All this, beside the necessary appliances for preserving the collections, was forwarded to Sydney early in the winter.

Commander Z. L. Tanner, U. S. N., was kind enough to superintend for me the building of the sounding machines and of the deep sea nets. We hoped to make large collections of pelagic animals both inside the Barrier Reef as well as at sea off the passages leading through the Great Barrier Reef. Unfortunately during our whole stay in the district of the reef boisterous weather prevented us from carrying out our plans for making pelagic collections, and we were compelled to limit our work mainly to the examination of the inner portions of the Great Barrier Reef district. Our most extended observations were made in the vicinity of Cook Town from the Hope Islands on the south to Lizard Island on the north. South of the Cook Town district the weather prevented us from making more than a rapid examination of many of the islands and reefs on our track. While thus gaining only a general knowledge of the structure of the Great Barrier Reef, it was, however, quite sufficient to give us an excellent conception of the causes which have brought about the existing conditions along the coast of Queensland adjoining the Great Barrier Reef. Although the English admiralty charts of the Great Barrier Reef are still far from complete, yet many of the sheets are sufficiently detailed to show the process of denudation and of erosion which has been going on along the northeast part of the coast of Australia.

Steaming along the coast and back and forth towards the outer edge of the Barrier Reef, one is at once struck with the broad belt of coral reefs, flanking on the east the navigable channel which extends between it and the mainland as far as Cape York, a belt diminishing greatly in width as one proceeds from the south, northwards. The soundings thus far taken off the outer edge of the Great Barrier Reef, though not very numerous, yet indicate sufficiently well the submarine

slope of the continent outside of the reef. They show that it varies greatly, being quite steep to the south of Break Sea Spit, beyond the range of the coral reefs, while off the barrier reef it shelves more gradually as we go northward and approach the extensive shallow submarine plateau uniting northeastern Australia with New Guinea. The depth of the inner navigable channel varies from six to seventy fathoms at its southern funnel-like opening, to a general average of from ten to sixteen fathoms northward as far as Cape York. The passages between the inner reefs and the reef patches leading from the inside channel to the inner edge of the very outer reefs vary in depth from ten to twenty-five or even thirty fathoms.

The many islands with which the coast of Queensland is studded are either detached single islands or small groups of islands, or even extended archipelagos, and with few exceptions they are at no great distance from the mainland. The aspect of the deeply eroded flanks of the coast mountains, the existence of extensive high table levels, characteristic of the adjacent islands also, plainly indicate, when taken together, that the coast of Queensland has for a long period been subjected to very extensive denudation and erosion, and that the islands occurring along its eastern face were once a part of the mainland. This supposition is fully confirmed by what is known of the geology and botany of the mainland and of the adjacent islands.

As a general rule, the islands farthest removed from the Queensland coast have been longest subjected to the agencies which have separated them from the mainland. Many of the more distant remnants of the mainland are now mere islets flanked by extensive flats, or they are steep isolated rocks or clusters of rocks with rounded and worn surfaces devoid of vegetation, or they are simply flats eaten away to below low water mark.

The conclusion seems inevitable that all the flats and reefs lying between the outer line of reefs and the mainland are but the remnants of former islands extending to the eastern edge of the continental plateau; islands which once formed a part of the eastern coast of Queensland, and have by erosion and by denudation gradually been separated from the mainland and reduced to the flats forming the outer reef flats of the Great Barrier Reef. This process has, according to the Queensland colonial geologists, probably been going on since the end of the Cretaceous period, and is even now going on at many points of the Queensland coast.

After the formation of the islands and islets and after their separation from the mainland, corals began to grow upon the eroded surfaces and flanks of the flats and banks, changing



them gradually to reef flats and flanking reefs. Comparatively few corals grow upon the reef flats proper; they are usually covered with dead corals, and it is upon the steep flanks or upper gentle slopes of the reef flats that corals flourish in greatest abundance from a depth of ten fathoms upward. Their principal belt of growth seems to be between seven and three fathoms, and often to low water mark.

The existence of alluvial deposits, at a depth of nearly one hundred feet, in the vicinity of Townesville, plainly indicates that previous to the last elevation of the Queensland coast, there has been a subsidence of at least that depth along the northern part of the eastern coast of Queensland. This subsidence, however, has only played an insignificant part in the formation of the Great Barrier Reef; it is to the extensive action of erosion and of denudation apparent in all directions that we must look for the main causes which have shaped the submarine plateau off the coast of Queensland and prepared it for the growth of the Great Barrier Reef. At first the denudation and erosion of the northeastern part of the Australian continent must have taken place only on the outer edge of the continental plateau and did not extend to that part of the continent which has subsequently been changed by the same causes to the present inner navigable channel. Thus an outer barrier reef alone may then have existed with an inner channel of perhaps fifteen fathoms depth, and a very narrow belt of an inner series of flats and reef flats with islands and islets off the then existing coast of Queensland; much as we now find a broad inner belt of flats and islets, and an inner navigable channel with its islands and archipelagos, lying within the older and outer reef belt in which all islands and islets have long ago been reduced to flats and reef flats, most of which do not rise to the level of the sea.

The very moderate subsidence which has taken place in comparatively recent times cannot have shaped the outlines of the present Australian continent and of its submarine extension. For this we must look back first to the subsidence which took place in Cretaceous times, next to the subsequent elevation of the Cretaceous beds and finally to the erosion and denudation to which these beds, since their elevation above the level of the sea, have for so long a period been subjected. It is on the upper part of these submarine slopes, dating back to an earlier geological period, but modified by erosion and denudation up to recent times, that during the present epoch corals have obtained a footing and built up the Great Barrier Reef of Australia.

How far the Cretaceous subsidence and the subsequent great elevation of these beds in Australia extended to the eastward,

is an interesting problem. Such an eastern extension of this subsidence and elevation would go far to explain the existence of the banks, islands and archipelagos of the Southern Pacific as formed by the denudation and erosion of a preëxisting continent or continental islands. For if it has extended generally over the Southern Pacific we could explain the formation of coral reefs upon the remnants of these Pacific Lands much as we have attempted to explain the presence of coral reefs off the coast of Queensland and between it and New Guinea. The subsidence and elevation having both antedated the present epoch, neither could have influenced the formation of the coral reefs of our epoch or have been the cause of the peculiar shape of the Atolls and Barrier Reefs of the South Pacific coral belt.

We also have evidence of the most positive kind that there has been an elevation of at least ten feet along the whole of the littoral belt of Queensland and as far east as the outermost edge of the Great Barrier Reef. Along the coast of the mainland and on some of the islands close to it, this is shown by the existence of a peculiar conglomerate first observed by Jukes and subsequently by others at Cape Upstart, and at other points of the Queensland coast. Farther east on some of the islands between the mainland and the inner edge of the barrier reef, the beach sand conglomerate is often elevated to the same height as the shore conglomerate. Finally it can be distinctly shown that the elevated shore conglomerates and beach rocks are merely outliers, indicating a more extensive elevation in which the whole of the Great Barrier Reef district was involved. Many of the inner reef flats and some of those close to the outer margin of the reef are edged with a belt of so-called negro heads, huge masses of coral, the remnants of the elevated coral reef which once flourished upon these flats. The elevated reef having been eroded and worn away left the outer flats generally covered with dead corals and coral fragments, while the flats of the inner series of reefs are usually fringed by a broad belt of large negro heads, the latter not having been reduced with the rest of the elevated reef of which they once formed a part. The surface of the negro heads\* is deeply pitted and honeycombed like the surface of the elevated coral reefs of Florida and of the northern coast of Cuba.

One cannot fail to be struck with the immense amount of silt held in suspension by the inner waters of the Great Barrier Reef. The rivers during the floods bring down large masses of deposit; the flanks of the coast mountains as well as

\* As far as I know, Flinders was the first to apply the term of "negro heads" to the remnants of the former elevated coral reef. The existence of such an elevated reef suggested itself on reading his description.

of the islands off the shore are constantly scoured by rain ; thus silt is carried over the whole of the bottom of the inner waters of the Great Barrier Reef. The shallower water of the main inner channel, in depths of ten fathoms or less, is far from clear ; it is only in the deeper channels of the inner reef flats, in eighteen or more fathoms in depth, that the water becomes clear. But even in those channels, and in the inner channels close to the outer edges of the reef, the bottom is not composed of coral sand silt, but is covered with blue mud derived from the adjacent continental or island shores and flats.

I hope soon to publish a more detailed account of our observations.

I have to thank the State Department at Washington, the Foreign office in London, and the Government of Queensland for the interest they took in this expedition and for the facilities for work offered me in consequence from every direction.



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HUBERT ANSON NEWTON, Professor of Mathematics in Yale University and for many years an associate editor of this Journal, died at his home in New Haven, Conn., on August 12, at the age of sixty-six years. A biographical sketch of Professor Newton will be given in a later number.

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## OBITUARY.

JOSIAH DWIGHT WHITNEY, Professor of Geology and Metallurgy at Harvard University, died on August 19th, at the age of seventy-six years. A notice is deferred until another number.

A. H. GREEN, Professor of Geology at the University of Oxford, died recently at the age of sixty-three years.

PROFESSOR PETER COLLIER, well known as an agricultural chemist, died on June 29, 1896, at the age of sixty-one years. He was graduated in arts at Yale College in 1861, and remained in graduate studies of chemistry until 1867, receiving meanwhile the degree of doctor of philosophy, and serving sometime as assistant in chemistry. His studies were under both the elder and the younger Silliman, and Johnson, Dana, and Brush, and along with a goodly number of students since well known in chemical science. From 1867 to 1877 he was Professor of Physics and Chemistry in the University of Vermont. During this period he became enlisted in agricultural chemistry, leading in farmers' institutes, writing in the public prints and the journals of agriculture, and awakening attention to the applications of science. He served as one of the scientific commissioners to the Vienna Exposition in 1873. In 1877 he was appointed to the post of Chief Chemist of the Department of Agriculture at Washington, in which he was engaged six years. The annual reports of the department for this period give account of his investigations. He entered with great spirit into the problems of sugar production, and of the cultivation of sorghum with the fullest economy. In 1884 he published a comprehensive work on this subject, with a critical examination of the methods of manufacturing sugar from sorghum, and of its use for fodder. In 1887 he took the post of Director of the New York State Agricultural Experiment Station, at Geneva, N. Y., in which he was engaged until he was attacked with the disease which terminated his life. At Geneva he instituted, with the chemists of the Station, careful chemical and practical experimentation upon cheese-making and other questions of the products of milk, his laboratories being well sustained for experimental work. Suffering a severe attack of illness in the summer of 1895, he rallied sufficiently in November to bear the journey to Ann Arbor, and remained in this place, drawing friends around him by his genial gifts of conversation, until his death in June. Dr. Collier was a man of much executive force, having a wide acquaintance with scientific men, showing himself a keen observer of the trend of scientific thought, and holding the high regard of all who knew him. Of his family, his wife, a sister of President James B. Angell, and a daughter survive him.

A. B. P.

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### SCIENTIFIC INTELLIGENCE.

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THE

# AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXXIII.—*On the Rate of Condensation in the Steam Jet*; by A. DEFOREST PALMER, JR., Ph.D. With Plate IV.

DURING his investigation on "The Condensation of Atmospheric Moisture," Prof. Barus,\* while working with a steam jet, observed that the region of condensed vapor terminated below in a surface similar to that surrounding the inner part of a Bunsen flame. Its lower limit was parallel to the plane of the nozzle and at a distance above it depending on the actuating pressure of the jet. At this surface the velocity of condensation downward is equal to the upward velocity of the steam, and this in turn is an inverse function of the distance from the origin. From a few preliminary measurements he was led to the opinion that the condensation velocity increased very rapidly with the pressure, and at his suggestion I have undertaken a further investigation of the subject by a photographic method similar to that employed by W. Michelson† in his study of the combustion velocity of explosive gas mixtures.

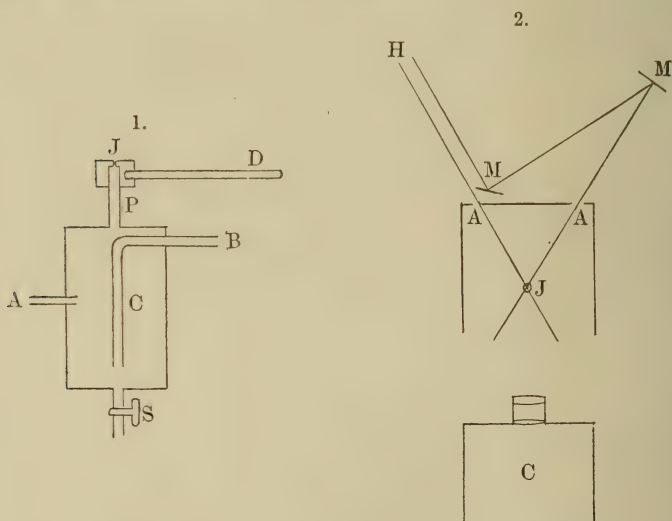
The calculation of the absolute velocity of condensation at any instant involves a knowledge of the specific volume of the steam and the curvature at every point of the surface of separation between the regions of condensed and non-condensed vapor. It is, however, probable that these two quantities are so related that the normal velocity is constant over the entire surface and hence may be expressed by the simple formula

$$U = \frac{vm}{S}$$

\* Bulletin No. 12, U. S. Department of Agriculture, Weather Bureau, 1895, p. 87.

† Wied. Ann., vol. xxxvi, p. 1, 1889.

where  $U$  is the velocity,  $v$  the mean specific volume at the surface,  $m$  the mass of steam issuing from the nozzle in unit time, and  $S$  the area of the surface;  $m$  and  $v$  are obviously complementary functions of the actuating pressure  $P$  of the jet, and the effect of their product on the variations of  $U$  with respect to  $P$  may be neglected in making the approximate determinations which alone are possible at the present time. For the calculation of  $S$  and its dependence on  $P$  a series of photographs of the jet were made and estimations attempted from measurements of the negatives, but it was found impossible to produce images having sufficient detail throughout to permit of accuracy by this method. However, the distance  $D$  from the plane of the nozzle to the lower limit of the surface could always be quite accurately determined, and, as this quantity varies directly with  $S$  and hence inversely with  $U$ , its values for different values of  $P$  serve as an index to the changes in  $U$ . Hence, while it is impossible to determine the absolute condensation velocity under any given conditions, a general idea of the nature of its variations may be obtained from a series of measurements of the distance  $D$ .



A brass compressed air tank of about three gallons capacity, heated by a large Fletcher burner and fitted with a Bourdon gauge reading from zero to thirty pounds pressure, was utilized as a boiler and connected by quarter-inch gas pipe to the drying apparatus illustrated in fig. 1. Here  $C$  is a chamber about three inches in diameter by eight inches high, made of steam pipe and connected at  $A$  with an open tube mercury manom-

eter by which the actuating pressure of the jet could be determined. A globe valve in the pipe B, through which steam is admitted, serves to regulate this pressure, and the stopcock S allows the water condensed in the chamber to be drawn off from time to time. The whole apparatus is inclosed in a wooden box and the free spaces filled with hair-packing to prevent radiation. The nozzle, situated above C and connected with it by a short eighth-inch gas pipe bored smooth on the inside to prevent condensation on its surface, was in the first construction simply a brass block screwed to the pipe P and having a hole at J about two millimeters in diameter for the formation of the jet. With this arrangement it was impossible at moderately high pressures to prevent spitting of the jet caused by particles of moisture condensing within the nozzle and being driven out by the rush of steam in such a manner as to entirely mask the ordinary aspect of the jet and render accurate measurement impossible. This difficulty was entirely overcome by screwing a brass rod D to the side of the brass block and heating its outer end in a Bunsen flame to such a degree that the heat conducted to the nozzle was just sufficient to prevent condensation on its inside walls. Ordinarily a jet formed under these conditions is quite invisible unless viewed against a black background, but if it be placed in a beam of direct sunlight and viewed from a point just outside that beam it appears very brilliant.

Satisfactory photographs of the jet, by reasonably short exposures, can be made only when it is very strongly illuminated by direct sunlight and the camera is placed as near as possible to the line of this light without allowing it to enter the lens. The arrangement of the apparatus to accomplish this end is illustrated in the diagram fig. 2. The jet, J, is situated in a three-sided black box having windows at AA about one inch wide and three inches high. Part of a beam of sunlight from a heliostat beyond H passes directly through J, while a second part, after reflection at the small mirrors MM, passes through J at an equal angle on the opposite side. The camera C is placed midway between these two beams and at a distance from J such that neither of them enters its lens. The back of the camera is provided with a stop having an aperture in its center one and one-half by two and one-half inches, and the plate holder is arranged to slide behind this in such a manner that ten images can be made on a five by eight plate. A rotating shutter attached to the lens and actuated by a weight is so regulated by a spring on its axis that the length of exposure can be varied within sufficiently wide limits. With this arrangement exposures of from one-tenth to one-half a second gave very satisfactory results, and the scale of the images was determined by photographing a millimeter scale so placed that



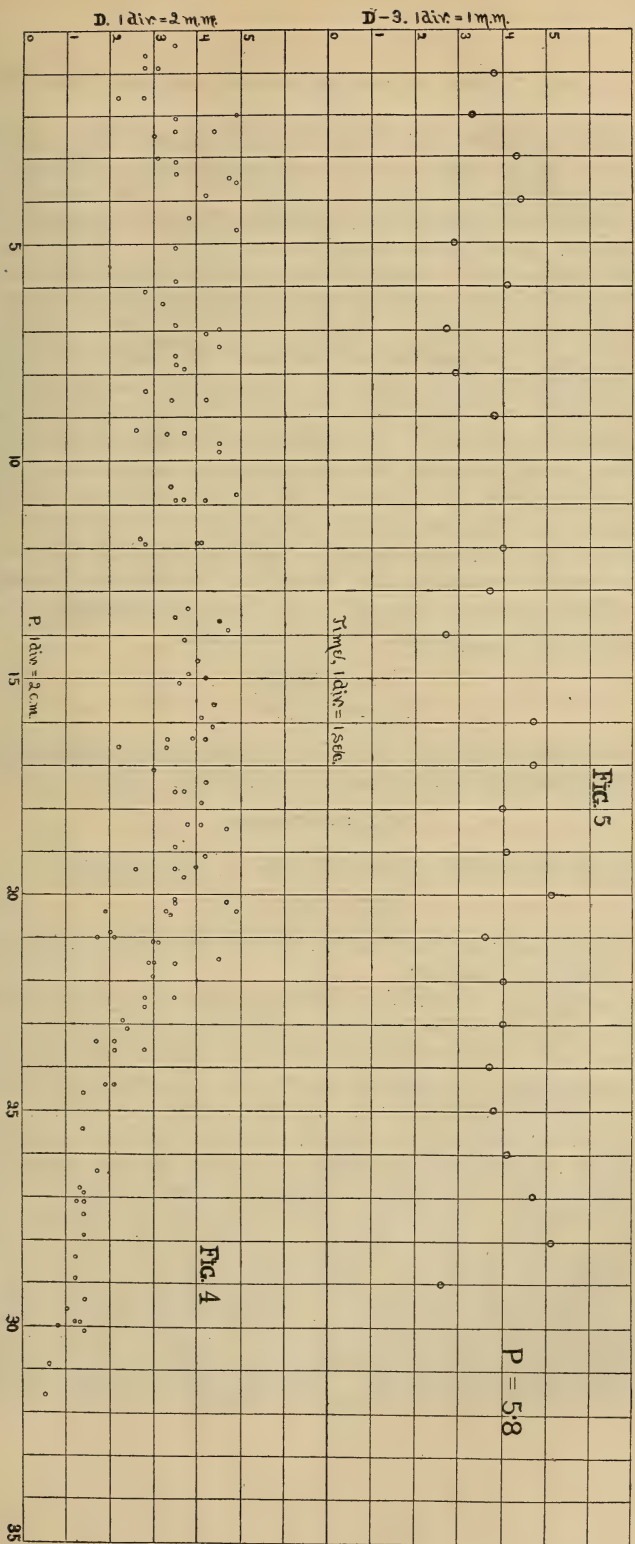
its plane contained the vertical axis of the jet and was perpendicular to that of the camera.

Fig. 3 (Plate IV) is a reproduction of one of the series of photographs, and though quite inferior to the negative in point of definition and detail, gives a very good idea of the general form of the jet. The values of  $P$  in centimeters of mercury and of  $D$  in millimeters, corresponding to this series, are given in the following table, the numbers being taken from left to right.

| No. | 1.   | 2.   | 3.   | 4.   | 5.   | 6.   | 7.   | 8.   | 9.   | 10.  |
|-----|------|------|------|------|------|------|------|------|------|------|
| $P$ | 43.8 | 42.3 | 40.8 | 37.8 | 35.3 | 30.3 | 19.6 | 36.8 | 28.3 | 13.8 |
| $D$ | 6.0  | 6.0  | 6.7  | 7.1  | 7.1  | 7.3  | 9.1  | 7.7  | 7.4  | 7.1  |

Fifty series of ten exposures each were made and the distances  $D$  corresponding to values of  $P$  up to about sixty-five centimeters of mercury very carefully measured on the negatives. Above this point the lower limit of condensation was always in coincidence with, or possibly below, the plane of the nozzle, showing that at very high pressures the condensation phenomena take place entirely within the nozzle. The result of these observations is shown graphically on the chart fig. 4, the abscissas being values of  $P$  to the scale one-half and the ordinates values of  $D$  to the same scale. All the points here represented have very nearly equal weight, and though errors of a few tenths of a millimeter might easily be made in the determination of  $D$ , the large variations in this quantity corresponding to the same pressure cannot be accounted for by errors of observation. Neither can they be explained by variations in the temperature and dust content of the air surrounding the jet, since the greatest change in this temperature during all the series of observations did not exceed two or three degrees centigrade as indicated on a mercury thermometer placed near the jet, and since many of the largest variations correspond to exposures the interval between which did not exceed a few seconds.

These considerations, together with the appearance of the image of the jet on the ground glass of the camera, led me to the opinion that the rate of condensation varied periodically, and hence that  $D$ , for moderate pressures at least, was a periodic function of the time. For the further study of this point I constructed a shutter having an electrical connection with the laboratory clock such that exposures of about one-tenth second could be repeated at intervals of one second. The actuating pressure being kept constant, a series of some thirty such exposures were made on the same plate and the distances  $D$  corresponding to each carefully determined. Eight such series of observations were made corresponding to different values of the pressure and the result of one of these is represented in fig. 5,



where the abscissas are times in seconds and the ordinates values of  $D-3$  in millimeters, the pressure being  $5.8^{\text{cm}}$  and the temperature of the surrounding air  $25.5^{\circ}\text{C}$ . The other series gave very similar results, and, while the time of exposure was too great to allow an accurate determination of the period in any case, the periodic nature of the phenomenon is established beyond doubt. If a series of photographs could be made by extremely short exposures rapidly following one another, it would probably be possible to accurately determine the amplitude and period of the function connecting  $D$  with the time, and hence also the dependence of these quantities on the actuating pressure of the jet. An attempt was made to accomplish this by utilizing the rapid discharges of a large Leyden jar battery as a means of illumination, but in no case was the light sufficient to produce measurable negatives.

Provided the temperature and dust content of the surrounding air remain constant, the velocities  $V_1$  of the ascending vapor at any point of the jet and  $V_2$  of the descending condensation may be expressed by the formulæ

$$\begin{aligned} V_1 &= f_1(H, P) \\ \text{and} \quad V_2 &= f_2(D, P) \end{aligned}$$

where  $H$  indicates height above the nozzle and the other letters retain the meaning already ascribed to them. If

$$H = D = \text{Constant}$$

and if  $P$  is constant it is obvious that  $V_1 = V_2$ , but if

$$H = D = x$$

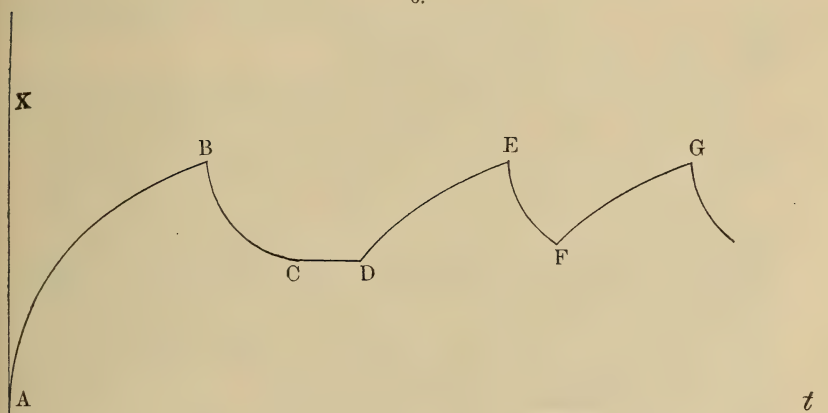
$V_2$  will be greater or less than  $V_1$  according as  $x$  is a decreasing or an increasing quantity.

The foregoing observations indicate that, the pressure being constant,  $x$  is a periodic but not a simple harmonic function of the time, and it is possible that the phenomena may be graphically represented as in fig. 6, where the abscissas indicate time and the ordinates values of  $x$ . At the origin  $V_2$  is zero. The steam, issuing from the nozzle, ascends with a gradually decreasing velocity and increasing degree of supersaturation until condensation commences, either spontaneously or induced by the entrance of dust particles from the surrounding air. The curve  $AB$  is thus traced, the velocity  $V_2$  at each point being equal to  $\delta x / \delta t$  and represented by the tangent to the curve. Beyond  $B$  the velocity which determines the value of  $x$  is obviously the resultant of  $V_1$  and  $V_2$ . At first  $V_2$  is very much the greater, and the representative point rapidly descends along some such curve as  $BC$ . During this operation the suc-



cessive positions of the limit of condensation correspond to constantly increasing values of the velocity  $V_1$ , and a point C is finally reached at which  $V_2$  is equal to  $V_1$ , and the curve becomes an horizontal straight line. This character is maintained until, for some unknown reason, condensation entirely ceases at D and the original phenomenon repeats itself, producing the curve DE identical with the upper part of AB. At E condensation again takes place and the representative point moves along the line EF in all respects similar to BC. It is quite possible that, as indicated at F, the cessation of condensation may take place before the point at which  $V_2 = V_1$  is reached, but however this may be, the curves lying between two successive beginnings of condensation should be repeated so long as the conditions remain the same. The figure shows two possible forms, B C D E and E F G, but does not assume to represent an actual case, which would probably consist of an indefinite repetition of the same form.

6.



Obviously  $V_2$  can never be less than the value of  $V_1$  corresponding to the lowest points of the curve, and if a definite horizontal portion could be determined from the observations its height above the axis would give the absolute value of the velocity of condensation under the given conditions. The observations above recorded, probably on account of the relatively large interval between them, give no definite evidence of this portion of the curve, but an attempt was made to determine a lower limit for  $V_2$  by the calculation of  $V_1$  for the lowest observed points corresponding to the same pressure. It was, however, found impossible to accomplish this, with more than a very rough degree of approximation, on account of the

lack of data regarding the distribution of pressure and specific volume throughout the jet, and I have, therefore, reserved this part of the work until measurements of these quantities can be made.

Turning now to the effect of the actuating pressure, it is obvious that both

$$V_1 = f_1(H, P) \text{ and } V_2 = f_2(D, P)$$

increase with  $P$ . If  $f_1$  and  $f_2$  increase at the same rate, the lowest points of the curves, similar to those of fig. 6, corresponding to different pressures will be all on the same level. If  $f_1$  increases faster than  $f_2$  the height of these points will increase with the pressure. Finally if  $f_2$  increases faster than  $f_1$  this height will decrease. The observations plotted in fig. 4 leave no doubt that the latter supposition is correct, and hence the velocity of condensation must increase in marked degree with the pressure. Furthermore since the initial velocity of the jet and the rate of decrease of  $V_1$  from the nozzle upward increase with the pressure, it is to be expected that the amplitude of the oscillations will decrease, and this expectation is amply born out by the observations.

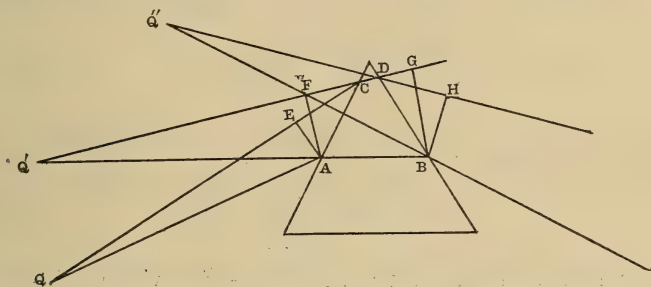
Regarding the abrupt cessation of condensation, as at D and F, fig. 6, Prof. Barus has suggested that it is possible that the heat of instantaneous condensation may be sufficient to superheat the advancing steam and thus destroy the supersaturation. In support of this view it may be remarked that the probable period of the oscillations is so short that very little heat escapes from the jet, and that, the latent heat of steam being 540 and its specific heat 0.5, sufficient heat is liberated by the condensation of one gram of steam to heat one gram of steam about 1000° C.

In concluding I wish to express my thanks to Prof. Barus for his kind suggestions and encouragement.

Wilson Physical Laboratory of Brown University, July 1, 1896.

ART. XXXIV.—*The Longitudinal Aberration of Prisms;*  
by CHARLES G. ABBOT and FREDERICK E. FOWLE, JR.

HAVING had occasion recently to consider the propriety of dispensing with collimation in the spectro-bolometric train at the Smithsonian Astrophysical Observatory, we have consulted with profit the equation given by Lord Rayleigh\* for the longitudinal aberration of a prism in the case of a cone of rays incident with the central ray in minimum deviation. We have had occasion in doing so to develop formulæ slightly differing from those of Lord Rayleigh, and have thought it not without interest to present the results of a somewhat closer approximation. In the following demonstration we have employed, so far as possible, the same notation as Lord Rayleigh to facilitate comparison.



Let QA be the central ray of the pencil incident at the angle for minimum deviation. Let the angles of incidence and refraction of QA be  $\phi$  and  $\phi'$  respectively. Let QC be a second ray incident at the angle  $(\phi + \delta\phi)$  and let the foci of the prism be Q' and Q''. The angles  $\angle AQC$  and  $\angle BQ'D$  are  $\delta\phi'$  and  $\delta\phi''$  respectively. And let AE, AF, BG and BH be perpendicular to QC, Q'C, Q'G and Q'H respectively. Let QA =  $u$ , Q'A =  $u'$ , Q''B =  $v$ , AB =  $l$ . Powers of  $\delta\phi$  higher than the first will be neglected.

$$AE = u\delta\phi \quad (1)$$

$$AC = \frac{AE}{\cos. (\phi + \delta\phi)} \quad (2)$$

$$AF = AC \cos (\phi' + \delta\phi') \quad (3)$$

$$u' = \frac{AF}{\delta\phi'} \quad (4)$$

$$BG = AF + l\delta\phi' \quad (5)$$

\* Philosophical Magazine, V, ix, p. 44, 1880.



$$BD = \frac{BG}{\cos(\phi' - \delta\phi')} \quad (6)$$

$$BH = BD \cos(\phi - \delta\phi'') \quad (7)$$

$$v = \frac{BH}{\delta\phi''} \quad (8)$$

But  $\mu \sin.(\phi' + \delta\phi') = \sin.(\phi + \delta\phi)$  (9)

whence  $\delta\phi' = \frac{1}{\mu} \cdot \frac{\cos \phi}{\cos \phi'} \delta\phi - \frac{1}{2\mu} \cdot \frac{\sin \phi}{\cos \phi'} \left(1 - \frac{\cos^2 \phi}{\mu^2 \cos^2 \phi'}\right) \delta\phi^2 \dots$  (10)

Similarly  $\mu \sin.(\phi' - \delta\phi') = \sin.(\phi - \delta\phi'')$  (11)

whence  $\delta\phi'' = \delta\phi$  (12)

Substituting these values, expanding and reducing we have,

$$v = u + \frac{e}{\mu} \cdot \frac{\cos^2 \phi}{\cos^2 \phi'} + \left\{ 2u \left( \tan. \phi - \frac{\tan \phi'}{\mu} \cdot \frac{\cos \phi}{\cos \phi'} \right) + \frac{l}{2\mu} \left( \frac{\sin \phi \cos \phi}{\cos^2 \phi'} - \frac{\tan \phi' \cdot \cos^3 \phi}{\mu \cos^3 \phi'} \right) \right\} \delta\phi. \quad (13)$$

and

$$\delta v = \left\{ 2u \left( \tan \phi - \frac{\tan \phi'}{\mu} \cdot \frac{\cos \phi}{\cos \phi'} \right) + \frac{l}{2\mu} \left( \frac{\sin \phi \cdot \cos \phi}{\cos^2 \phi'} - \frac{\tan \phi'}{\mu} \cdot \frac{\cos^3 \phi}{\cos^3 \phi'} \right) \right\} \delta\phi. \quad (14)$$

For the rays incident at the angle  $(\phi - \delta\phi)$  we must give  $\delta\phi$  the negative sign in these expressions. Hence if  $v_1$  and  $v_2$  are the focal distances for the rays incident at the angles  $(\phi + \delta\phi)$  and  $(\phi - \delta\phi)$  respectively, we may express  $v_1$  and  $v_2$  as follows:

$$v_1 = u + Al + B\delta\phi + C\delta\phi^2 + D\delta\phi^3 + \dots \quad (15)$$

$$v_2 = u + Al - B\delta\phi + C\delta\phi^2 - D\delta\phi^3 + \dots \quad (16)$$

where A, B, C and D are factors independent of  $\delta\phi$ ;

whence  $v_1 - v_2 = 2B\delta\phi + 2D\delta\phi^3 + \dots$  (17)

or, neglecting powers of  $\delta\phi$  higher than the second, the total longitudinal aberration  $\Delta v$  is

$$\Delta v = 2B\delta\phi \quad (18)$$

where  $B = 2u \left( \tan \phi - \frac{\tan \phi'}{\mu} \cdot \frac{\cos \phi}{\cos \phi'} \right) + \frac{l}{2\mu} \left( \frac{\sin \phi \cdot \cos \phi}{\cos^2 \phi'} - \frac{\tan \phi'}{\mu} \cdot \frac{\cos^3 \phi}{\cos^3 \phi'} \right)$  (19)

For comparison with Lord Rayleigh's equation (19) we derive from equations (4), (3) and (6)

$$u' = \frac{FA}{\delta\phi'} = u \frac{\delta\phi}{\delta\phi'} \cdot \frac{\cos(\phi' + \delta\phi')}{\cos(\phi + \delta\phi)} \quad (20)$$

$$AC = y = \frac{u\delta\phi}{\cos(\phi + \delta\phi)} = \frac{u'\delta\phi'}{\cos(\phi' + \delta\phi')} \quad (21)$$

$$BD = y' = \frac{AF + l\delta\phi'}{\cos(\phi' - \delta\phi')} = \frac{(u' + l)\delta\phi'}{\cos(\phi' - \delta\phi')} \quad (22)$$

whence 
$$\frac{y'}{y} = \frac{u' + l}{u'} (1 - 2 \tan \phi' \cdot \delta\phi' + \dots) \quad (23)$$

That the approximations made in equations (19), (24) and (25) of Lord Rayleigh's article may be of significance as materially affecting the value of  $\delta v$ , is shown by calculations made with the following data:

$$\begin{array}{lll} u = 1000^{\text{cm}}, & l = 6.5^{\text{cm}} & \phi = 50^\circ 12' 20'', \\ y = 5.5^{\text{cm}}, & \delta\phi = 12' 3'', & \phi' = 30^\circ 0' 0'', \quad \mu = 1.5367 \end{array}$$

Lord Rayleigh's formula gives:

$$\delta v = 9.7^{\text{cm}}$$

The formula deduced above gives:

$$\delta v = 6.5^{\text{cm}}$$

Astrophysical Observatory, Smithsonian Institution, June 15, 1896.

ART. XXXV.—*Abnormal Hickory Nuts*; by FRANCIS HOBART HERRICK. With Plate V.

THERE are preserved in the collections of the Kirtland Society of Natural Science, now incorporated with those of Adelbert College of Western Reserve University, two specimens of abnormal hickory nuts of a unique and singular character. They have never been described, but were always regarded with the greatest interest by the pioneer naturalist of the Western Reserve, the late Dr. Jared P. Kirtland. The nuts were kept in a glass case which bore a label neatly written by Dr. Kirtland, giving the only history of them which has been preserved.

This label reads as follows: "D. G. Streator, M.D., collected in autumn last (1875) a quart of these nuts, under a hickory tree, overspread by a larger black oak, in the town of Windham, Portage Co., Ohio. Externally they resembled hickory nuts, but internally each contained a perfectly formed acorn, stem, and excessively bitter meat, like the numerous acorns of the black oak."

"The specimens and foregoing facts were furnished me by T. Garlick, M.D. Both he and Dr. Streator are residents of Bedford, Cuyahoga Co., Ohio."

The persons mentioned by Dr. Kirtland are dead, and there is probably no one now alive who could throw any light from personal knowledge upon the statement just quoted.

It seemed to me that a careful analysis of the structure of these nuts might prove of interest. Accordingly I have studied their histological structure, and compared it with that of the normal hickory nut, and incidentally with that of the acorn.\*

The general appearance of the two nuts is very similar from without, and when cracked open they show an inclosed acorn-like nut, as is well shown in the photograph (fig. 1, *a-e*, Plate V). The outer husk or exocarp is not preserved, so that nothing is known of its appearance. The endocarp or nut proper of the abnormal specimens consists of a thick and very dense outer shell, which is moulded upon a smaller inner nut. This inner nut resembles an acorn in form, and is attached to a distinct stem (fig. 1, *a*) which separates readily from the rest of the nut. The stem is fastened to the acorn-like body by an expanded cup-shaped end, which recalls the cupule of the oak. The wall is less dense over the area of attachment than in the other parts of the nut, forming a circular hilum which resembles that of an acorn. These facts are illustrated by fig. 1,

\* I am much indebted to my colleague, Professor H. P. Cushing, for the skillful preparation of thin sections of all the nuts examined.



*a-c* and by the drawings of the profile and transverse sections of the normal and abnormal nuts (figs. 2, 3, 4, 5).

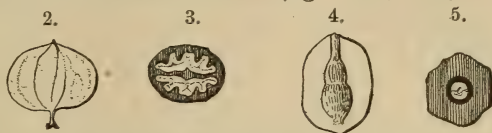
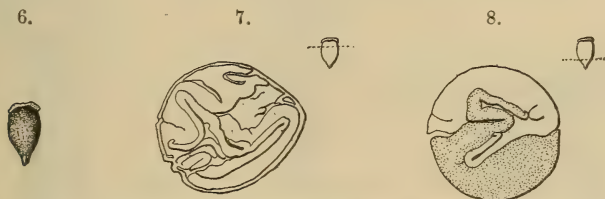


Figure 4 is a line drawing of fig. 1, *b*, and shows the profile of the nut, and one-half of the mould, so to speak, of the inner nut and its stem. In the transverse section of the normal hickory nut (*Carya sulcata*) the outline is generally oval and the two folded halves of the meat are seen (fig. 3). In the abnormal nut (fig. 5) the form of the endocarp at the outer surface is markedly hexagonal, while the dense shell of the inner nut appears as a ring (represented black to differentiate it) and within this are the compacted intertwined cotyledons of the meat.



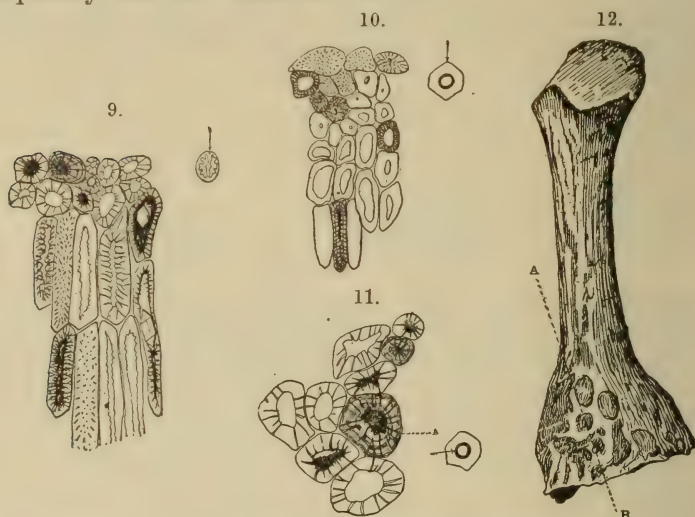
The meat of one of the nuts when removed (fig. 6), though preserved for twenty-one years, had not perceptibly shrunk. It was covered with a dark brown skin, and capped with a thin disk of tissue corresponding to the hilum of the stalk. There were slight longitudinal creases on its surface, and in transverse sections taken at different levels (figs. 7, 8) we see the complicated foldings of the two cotyledonous leaves. This nut had a slightly bitter, but not unpleasant, aromatic taste.

#### *Histology of the normal endocarp.*

Part of a transverse section of a normal nut is illustrated in fig. 9, the position of the area drawn being shown at the upper corner to the right. Near the surface are several tiers of sclerenchyma, its cells being of relatively small size, with thick walls of a light brown color and penetrated by numerous branching canals. The lumina of these dead cells and the canals are partially or completely filled with a dark brown deposit. They also contain characteristic crystals, often of relatively large size. Then follow several tiers of elongated cells, then a thicker stratum of sclerenchyma, whose irregular cells are cut in various planes. Finally the folded inner surface of the endocarp next to the meat is carpeted by a thin layer of deep brown color, the metamorphosed product of several strata of flattened cells.

*Histology of the abnormal endocarp.*

The dense outer shell of the abnormal nut (fig. 10) resembles closely in structure the normal endocarp just described, except that the tissue is rather more compact and the cells are smaller. (Compare figs. 9 and 10.) The cell-wall has a similar structure. There is the same kind of brown indurated matter filling the lumina of the cells, and the same kind of crystals are occasionally seen. The structure of the dense wall of the inner shell surrounding the nut is quite uniform, as represented in fig. 11, from a transverse section. The cell-walls in this are thick, laminated, and perforated by numerous canals, many of which branch and communicate with the canals of adjoining cells. (See cell *a*, fig. 11.) The brown indurated material frequently fills both canals and lumen.



The stem (figs. 1-a and 12) by which this inner nut was attached to the tree, is an interesting structure. As shown in the photograph, it has separated in one specimen from the nut, and terminates in a shallow cup or expansion which suggests the cupule of the acorn.

It is light in color streaked with dark brown lines, which assume the form of islands or irregular blotches at the expanded end next the nut. A section, cut in the plane indicated in fig. 12, has a singular appearance. It presents a finely mottled pattern, and when examined microscopically is seen to consist of colorless and colored sclerenchyma. The light brown cells, which owe their color to the indurated cell-contents, form a reticulated pattern. The tissue shows no direct or unmistakable evidence of imbrication in the plane sectioned, but I regret that the section did not pass through the axis of the stem.

The meat of the first abnormal nut (fig. 1, *c*) is represented in fig. 6, as it appears when removed from its inner shelly covering. The fact that the meat was white and fresh, and as already stated, not devoid of taste, after the lapse of twenty-one years, argues well for the density and impenetrability of its shelly coverings.

The parenchymatous cells near the surface of the cotyledon are smaller than in the normal hickory nut (*Carya sulcata*), and abound in starch and oil. In the normal nut the cells are of larger size and contain very much less starch and more oil.

The second nut (fig. 1, *e*) which I planted in earth after cracking the inner shell, failed to germinate, though I gave it warmth and moisture for several months. But since some acorns and other nuts which were planted at the same time and in the same pot, died, it is evident that the conditions of growth were for some unknown reasons unfavorable, and possibly under better auspices germination might have taken place.

Sections through the meat show two cotyledons, crumpled and folded upon each other in a very complex manner (figs. 7, 8). The parenchymatous cells appear to be normal. They are packed with minute ovoidal starch grains.

#### *The origin of the abnormal variety.*

It has been seen that Dr. Kirtland considered this variation in the hickory as a result of hybridism with the oak, the only evidence of this being the peculiar form of the inner nut, resembling indeed an acorn in general appearance, the circumstances that the hickory was overshadowed by an oak, and the bitterness of the nut.

The fact that the inner nut resembles an acorn in general appearance, and is attached by a definite stem which ends in an expansion within the endocarp is indeed striking, but I find nothing in the histology of these parts to show that this resemblance is anything more than superficial. The sclerenchyma of the inner nut is far more like that of the endocarp of the hickory than that of the oak.

Supposing that hybridism between two such families of plants as the oak and the hickory possible, it could rarely happen since the oaks of this region flower a week or more in advance of the hickories. So that if hybridism did occur in this instance, the flowering of the one species must have been abnormally delayed, or that of the other abnormally accelerated.

On May 15th of this year I gathered some young nuts of the hickory near Cleveland which were perhaps a week old and measured over the exocarp in one case  $5 \times 8$  millimeters. The



endocarp has at this early stage, as we would expect, the form characteristics of the mature nut. Normal fertilization thus leads very early to the normal outlining of the fruit.

While I can find no direct evidence of hybridism from a study of the minute anatomy of the structure, I consider it highly probable that this variation arose at the time of fertilization, which was in some way abnormal, and must content myself for the present with giving the known facts. When similar cases are discovered, they may afford botanists more secure ground for speculations in regard to their cause.\*

Adelbert College, May, 1896.

#### DESCRIPTION OF FIGURES.

- FIGURE 1, Plate V.—*a*. Internal stem removed from abnormal nut (A).  
*b*. Half of endocarp of abnormal nut (A), showing the "mould" of the stem and inner nut.  
*c*. Half of endocarp (A) showing the internal acorn-like nut.  
*d*. Half of endocarp of abnormal nut (B) from the outer side.  
*e*. Half of endocarp of abnormal nut (B) from inside. In this case the fusion of the stem to the inner nut was more complete.  
 All from photograph. Natural size.
- FIGURE 2.—Endocarp of *Carya sulcata* (Western Shell-bark Hickory). Lateral view. One-half natural size.
- FIGURE 3.—Transverse section of the same, showing normally folded cotyledons within the shell. One-half natural size.
- FIGURE 4.—Half of abnormal endocarp (A). Line drawing of fig. 1. *b*. One-half natural size.
- FIGURE 5.—Endocarp of abnormal nut (A) seen in transverse section, showing outer shell, shell of inner nut (shaded black), and folded cotyledons. One-half natural size.
- FIGURE 6.—Meat of abnormal nut (A) removed from inner shell, some of the tissue of the hilum clinging to the top. Natural size.
- FIGURE 7.—Transverse section through the meat of abnormal nut (A) showing foldings of the cotyledons, in the plane indicated at the right. Four times natural size.
- FIGURE 8.—Transverse section through meat of abnormal nut (A), showing foldings of the cotyledons, in plane indicated at the right. four times natural size.
- FIGURE 9.—Part of transverse section of endocarp of normal hickory nut from point indicated at the right, showing superficial sclerenchyma, the tiers of deeper cells lying vertical to the surface. The cell-walls are pierced with numerous branching canals, and enclose crystals (possibly calcium oxalate) and secondary deposits of a brown color.  $\times 124$ .
- FIGURE 10.—Part of transverse section of abnormal endocarp (A), taken from a point near surface indicated at the right.  $\times 124$ .
- FIGURE 11.—Sclerenchyma from transverse section of shell of inner nut from point near surface shown at right.  $\times 124$ .
- FIGURE 12.—Stem of abnormal nut (A). Lateral view. Enlarged about four times.

\* The interesting communication, in Bulletin of the Torrey Botanical Club, 1880, p. 54, noting the occurrence of fruits having a very thick endocarp and possessing a transformed axis, should be examined in connection with the case here mentioned.

ART. XXXVI.—*The Separation and Identification of Potassium and Sodium*; by D. ALBERT KREIDER and J. E. BRECKENRIDGE.

[Contributions from the Kent Chemical Laboratory of Yale University—LVI.]

THE application of the spectroscope to the detection of potassium and sodium, for which there has thus far been no alternative, is not so unsatisfactory in the evidence as to the presence or absence of these elements as it is in its utter failure, except under delicate quantitative comparisons, to give any idea as to the quantity of either element indicated; and since the most minute quantity of either element is sufficient to produce its characteristic line in the spectroscope, together with the fact that so many of the reagents employed in analysis contain a trace of alkali, the indication of the spectroscope is rendered misleading. While to the careful observer the presence or absence of potassium is invariably revealed, all evidence as to the ubiquitous element sodium is practically worthless. It has, therefore, appeared advisable to us to undertake the following work looking toward a method for the direct determination of sodium based upon the principle of the perchlorate method for the quantitative determination of potassium. The fact that, in the form of the perchlorate, potassium is insoluble while sodium is readily soluble in 97 per cent alcohol, affords a means for the separation of the two elements as well as for the identification of the former. By converting the sodium in the filtrate from the precipitated potassium salt either to the chloride or sulphate, in which forms it is insoluble in alcohol, a means for the detection of sodium is also provided.

Assured by the experiments previously published by one of us,\* that the determination of potassium according to this method would be sufficiently accurate, our experimentation was directed towards determining the conditions of greatest utility and delicacy for the detection of sodium. In converting the sodium from the perchlorate to the chloride, attempts were first made to substitute some soluble chloride for the free acid, the addition of which to the alcoholic solution of sodium perchlorate, it was feared, might result in the formation of the dangerously explosive compound, perchloric ether. But aniline hydrochloride, prepared by saturating a solution of aniline in absolute alcohol with gaseous hydrochloric acid, when applied to the precipitation of 0.010 grms. of sodium perchlorate dissolved in 5 cm<sup>3</sup> of 97 per cent alcohol, proved so hopelessly inadequate that we resorted immediately to the use of free acid, which, fortunately, was found perfectly safe

\* Kreider, this Journal, vol. xlix, 448.

even in the presence of considerable perchloric acid and at the boiling point of the mixture.

The strongest aqueous solution of hydrochloric acid, however, is inapplicable, as was proved by several experiments in which as much as 0.010 grms. of sodium perchlorate, dissolved in only 5 cm<sup>3</sup> of 97 per cent alcohol, failed to be revealed by the addition of the strongest aqueous solution of the acid, added in quantities varying from a single drop to 10 cm<sup>3</sup>—not the slightest turbidity being produced. By substituting for the aqueous solution of the acid, a saturated solution of hydrochloric acid in 97 per cent alcohol, of which 5 cm<sup>3</sup> were used for the precipitation, quantities of from 0.002 to 0.003 grms. of sodium perchlorate dissolved in 5 cm<sup>3</sup> of 97 per cent alcohol could be detected with certainty; but this could not be made sufficiently delicate. Concentrated sulphuric acid was also applied as the precipitant and was found reliable for quantities of about 0.003 grms. of sodium perchlorate dissolved in 10 cm<sup>3</sup> of 97 per cent alcohol, when a single drop of the acid was added, but an excess of the acid caused the precipitate to redissolve. Gaseous hydrochloric acid proved most effectual. The dehydrating effect of the acid upon the alcohol greatly increases the insolubility of sodium and secures a remarkable delicacy, as is evident from the results recorded in Table I.

TABLE I.

| NaClO <sub>4</sub> taken,<br>grms. | Na <sub>2</sub> O equivalent,<br>grms. | 97% alcohol,<br>cm <sup>3</sup> . | Indication. |
|------------------------------------|--|-----------------------------------|-------------|
| 0.0100                             | 0.00250                                | 10                                | very strong |
| 0.0050                             | 0.00125                                | "                                 | strong      |
| 0.0040                             | 0.00100                                | "                                 | "           |
| 0.0030                             | 0.00075                                | "                                 | "           |
| 0.0030                             | 0.00075                                | "                                 | good        |
| 0.0020                             | 0.00050                                | "                                 | "           |
| 0.0020                             | 0.00050                                | "                                 | "           |
| 0.0010                             | 0.00025                                | "                                 | "           |
| 0.0005                             | 0.00012                                | "                                 | trace       |
| 0.0003                             | 0.00006                                | "                                 | "           |
| 0.0001                             | 0.00003                                | "                                 | none        |
| 0.0000                             | 0.00000                                | "                                 | "           |
| 0.0010                             | 0.00025                                | 40                                | distinct    |

The sodium employed in these determinations was in the form of perchlorate, prepared by evaporating sodium chloride, free of potassium and ammonium, with perchloric acid until tests for hydrochloric acid proved a complete conversion to the perchlorate, when the excess of acid was volatilized by heating over a drying cone. Two grams of this purified salt were dissolved in 200 cm<sup>3</sup> of 97 per cent alcohol and served for our standard solution for those tests in which quantities greater than 0.001 grms. of sodium perchlorate were used. When it



appeared evident that smaller quantities could be detected with certainty, a solution of the salt containing 0.050 grms per 100 cm<sup>3</sup> of water was used, and each portion evaporated to dryness before adding the alcohol. In each case the alcohol subsequent to its addition was saturated with gaseous hydrochloric acid, being kept cool by immersion in a beaker of water. For the generation of hydrochloric acid, the well known form of apparatus consisting of a side neck flask, containing sodium chloride covered with hydrochloric acid fitted with a stoppered funnel, through which sulphuric acid could be admitted as desired, served admirably.

It is evident, then, that by the use of 10 cm<sup>3</sup> of 97 per cent alcohol with gaseous hydrochloric acid 0.0003 grms. of sodium oxide can be found with certainty; and when the alcohol is allowed to become saturated with the gas even 0.00006 grms. of sodium oxide will be unmistakably revealed. The quantity of alcohol, 10 cm<sup>3</sup>, is sufficient for all purposes, since this amount will dissolve about two grams of sodium perchlorate; but even in 40 cm<sup>3</sup> 0.0002 gm. of sodium oxide may be seen distinctly; from which fact it is evident that this method can be applied to the quantitative determination of sodium. Absolute alcohol does not materially increase the delicacy of the test.

In Table II are recorded the results of experiments made upon mixtures of the two elements. The sodium and potassium taken were drawn from separate standard solutions containing one gram of the purified perchlorates in 100 cm<sup>3</sup> of distilled water. After evaporating to dryness on the steam bath, the residue was treated with the usual amount of 97 per cent alcohol, the insoluble potassium perchlorate was removed by filtering through a dry paper filter and dry funnel into a dry test tube, and the filtrate saturated with gaseous hydrochloric acid.

TABLE II.

| KClO <sub>4</sub><br>taken.<br>grms. | K <sub>2</sub> O<br>equivalent.<br>grms. | NaClO <sub>4</sub><br>taken.<br>grms. | Na <sub>2</sub> O<br>equivalent.<br>grms. | Indication<br>for<br>potassium. | Indication<br>for<br>sodium. |
|--------------------------------------|--|---------------------------------------|---|---------------------------------|------------------------------|
| 0.0500                               | 0.01699                                  | 0.0500                                | 0.01250                                   | strong                          | strong                       |
| 0.0200                               | 0.00680                                  | 0.0200                                | 0.00500                                   | "                               | "                            |
| 0.0100                               | 0.00340                                  | 0.0100                                | 0.00250                                   | "                               | "                            |
| 0.0050                               | 0.00170                                  | 0.0050                                | 0.00125                                   | "                               | "                            |
| 0.0040                               | 0.00136                                  | 0.0040                                | 0.00100                                   | good                            | good                         |
| 0.0030                               | 0.00102                                  | 0.0030                                | 0.00075                                   | "                               | "                            |
| 0.0020                               | 0.00068                                  | 0.0020                                | 0.0005                                    | "                               | "                            |
| 0.0010                               | 0.00034                                  | 0.0010                                | 0.00025                                   | "                               | "                            |
| 0.0005                               | 0.00017                                  | 0.0005                                | 0.00012                                   | trace                           | trace                        |
| 0.0003                               | 0.00010                                  | 0.0003                                | 0.00007                                   | "                               | "                            |
| 0.0001                               | 0.00003                                  | 0.0001                                | 0.00003                                   | faintest trace                  | none                         |
| 0.0000                               | 0.00000                                  | 0.0100                                | 0.00250                                   | none                            | strong                       |
| 0.0100                               | 0.00340                                  | 0.0000                                | 0.00000                                   | strong                          | none                         |

These results prove that the two elements when combined in any proportion may be separated and identified with great delicacy.

Before applying this method, however, it is necessary to remove certain interfering substances. While potassium may be safely tested for in the presence of other bases and acids, except ammonium, caesium and rubidium, and sulphuric acid\* the large number of elements whose chlorides are insoluble in alcohol necessitates their removal before testing for sodium. But among the common alkalies ammonium is the only one whose presence is objectionable. Lithium does not affect either the test for potassium or sodium, as was determined by an experiment in which about 0.1 grm. of lithium chloride was converted into the perchlorate by evaporating with an excess of perchloric acid and treated with 10 cm<sup>3</sup> of 97 per cent alcohol. A perfectly clear solution was obtained, which upon saturation with gaseous hydrochloric acid and cooling, remained clear. The removal of sulphuric acid is necessitated by the insolubility of sodium sulphate in alcohol.

TABLE III.

| Bases taken.   |         | K <sub>2</sub> O<br>taken.<br>grms. | Na <sub>2</sub> O<br>taken.<br>grms. | Indication<br>for<br>potassium. | Indication<br>for<br>sodium. |
|--|---------|-------------------------------------|--------------------------------------|---------------------------------|------------------------------|
| Pb. Cu. Al. Fe. Zn.<br>Ba. Ca. and Mg. as nitrates.<br>grms. |         |                                     |                                      |                                 |                              |
| 0.0500   | of each | 0.0000                              | 0.0000                               | faintest trace                  | trace                        |
| 0.0500   | "       | 0.0017                              | 0.0012                               | good                            | good                         |
| 0.1000   | "       | 0.0000                              | 0.0000                               | faintest trace                  | trace                        |
| 0.1000   | "       | 0.0000                              | 0.0005                               | "                               | good                         |

In the experiments made with potassium and sodium associated with other acids and bases, the results of which are recorded in Table III, the following treatment was adopted. The several groups of bases were successively removed in the ordinary way: Hydrogen sulphide in ammoniacal solution removed the lead, mercury, copper and zinc. Barium and calcium were removed by ammonium carbonate, the final filtrate being evaporated and ignited to the complete volatilization of ammonia. The residue was dissolved and treated with barium hydrate for the removal of magnesium, and after filtering the barium was again removed by ammonium carbonate and the filtrate evaporated and ignited as before. This residue was then treated with 10 cm<sup>3</sup> of boiling water and after stirring was filtered in order to remove the organic matter usually found at this stage of the treatment. To the filtrate was added 0.1 to 0.5 cm<sup>3</sup> of pure perchloric acid, about 1.7 sp. gr., according to the amount of residue, and evaporated over the steam bath until the white fumes of perchloric acid appeared. When the quantity of sodium is large it is safer to evaporate several times in order to secure a complete conversion to the per-

\* Loc. cit.

chlorate, and in such case precautions must be taken to have sufficient of the acid present. Upon treating with 97 per cent alcohol the presence of potassium is revealed by an insoluble residue. This is removed by a dry filter and the filtrate saturated with gaseous hydrochloric acid, whereupon sodium, if originally present in amount greater than 0.0005 grms. of the oxide, will be precipitated in granular condition.

The fact that minute traces of sodium and potassium are found in the blank tests is to be expected from the delicacy of the method as proved by Tables I and II, when it is remembered that but very few of the so-called chemically pure reagents are absolutely free of sodium and that even distilled water kept in glass vessels contains a trace of the alkaline elements. However, the indication for sodium in the blank tests appeared only as a cloudiness and after complete saturation, while when the quantity of sodium oxide present is not less than 0.0005 the precipitate appears in granular form and before the alcohol is completely saturated, which leaves the method all that could be desired for qualitative determinations.

*Preparation of the Perchloric Acid.*—The perchloric acid prepared according to the method previously published by one of us,\* by converting sodium chlorate into the perchlorate by heat, destroying the residual chlorate by treating with the strongest hydrochloric acid, from which the sodium chloride was separated by filtering through a Gooch filter and the excess of hydrochloric acid removed by evaporation—while answering perfectly well for the detection of potassium, is inapplicable to the test for sodium, because of the small amount of this element which the acid always contains, due to the partial solubility of sodium chloride in hydrochloric acid. As distillation seems the only method for the removal of this residual sodium, our attention was given to a study of the best conditions for the distillation. Various experiments led to the adoption of the following treatment, which we found in every case perfectly safe and fairly rapid. To prevent loss by decomposition the distillation must be carried on under diminished pressure, and unless the acid has been previously concentrated by evaporating until the white fumes appear, if there is any considerable amount of the acid in the distilling flask, even with porcelain chips to check it, it bumps with such violence as to throw the liquid to all parts of the flask and possibly into the condenser. It appeared to be essential, therefore, to start with only a small amount of the concentrated acid in an apparatus which would permit of the gradual addition of the acid without relieving the vacuum. Rubber stoppers or connectors are not advisably used where the acid may condense upon them and flow back into the flask. Invariably oxidizable matter is carried back,

\* Kreider, this Journal, vol. xlix, 443.



causing explosions which vary in force and seriousness according to circumstances.

We, therefore, selected a strong distilling flask of about 100 cm<sup>3</sup> capacity and sealed into the tubulation a stoppered funnel which reached well into the bulb. The stop-cock of this funnel was carefully cleansed of vaseline and lubricated with metaphosphoric acid obtained by boiling syrupy orthophosphoric acid until the temperature of 350° C. had been attained.\* The side neck of the flask was inclined upward for a short distance before being bent into the receiver, with which it was connected by a rubber stopper through which the tube extended for a safe distance. An ordinary bottle of 250 cm<sup>3</sup> capacity served for a receiver and was closed by a doubly perforated stopper. Through one of the perforations the adapter from the condenser was entered; through the other connection was made with a small glass bulb inserted between the receiver and the next tube, containing moistened sticks of caustic potash, in order to prevent the potash from reaching the receiver in case of an accident to the pump. The object of the potash was to absorb any chlorine resulting from the inevitable slight decomposition of the acid, and thus to protect the mercury of the pump. For the exhaustion an automatic pump was employed and generally twenty minutes would suffice to reduce the pressure to about 8<sup>mm</sup>, when the distillation was begun. The pump gradually reduced the pressure, which was kept at about 3 to 5<sup>mm</sup>. The bottom of the distilling flask was covered with a layer of fine porcelain chips to a depth of about 1 cm<sup>3</sup> and the whole flask was surrounded by a cylinder of thin sheet iron closed below, while the upper opening was protected by an albestos cover. By this means heat was uniformly applied to every part of the flask and up to the point at which, if the acid condensed, it would flow into the receiver. Three or 4 cm<sup>3</sup> of the acid were admitted to the flask, after which the temperature was raised to about 130° C. and the acid admitted at about the same rate that it dropped from the condenser, care being taken to prevent the liquid in the distilling flask from disappearing entirely. No danger was experienced in admitting the acid; the porcelain chips distribute the heat and prevent the colder acid from reaching the glass.

Careful compliance with the above conditions will secure satisfactory results. As a rule we succeeded in distilling at the rate of 25 cm<sup>3</sup> to 40 cm<sup>3</sup> per hour, and when it is remembered that the product is the dihydrate of perchloric acid, the most concentrated form in which it is stable, and of which 0.1 gm. of potassium oxide requires only 0.16 cm<sup>3</sup>, it will be seen that by this process the acid may be prepared without great difficulty.

\* This lubricant will be found entirely satisfactory and greatly preferable to vaseline in many other operations where the greasy effect of the latter is objectionable.

ART. XXXVII.—*On the Estimation of Cadmium as the Oxide*; by PHILIP E. BROWNING and LOUIS C. JONES.

[Contributions from the Kent Chemical Laboratory of Yale University—LVII.]

IN an article entitled "The Estimation of Cadmium" \* Max Muspratt discusses critically some of the methods in use for the determination of that element. Muspratt finds that the method which involves the precipitation as carbonate, ignition and weighing as oxide gives low results, and he accounts for these results by the well known tendency of cadmium to reduction, especially in the presence of organic matter. To avoid this reduction he dissolved the precipitated carbonate in nitric acid, evaporated to dryness on a water bath, and gently ignited the nitrate to the condition of the oxide. This treatment also gave low results, although the oxide obtained from the ignition of the nitrate was found to contain traces of sulphate from the solution of the cadmium sulphate used. A second method of treatment was to filter and dry the precipitated carbonate and remove as much of it as possible to a weighed porcelain crucible, ignite and weigh by itself. This oxide was found to be free from traces of sulphate.†

The remainder of the cadmium oxide adhering to the paper was dissolved in pure nitric acid and the solution and rinsings evaporated to dryness and ignited in a weighed crucible and weighed. Here also low results were obtained which, after the extended process of manipulation, would scarcely seem surprising. If, however, Muspratt adds, the oxide obtained from the ignition of the carbonate be taken as  $\text{Cd}_2\text{O}$  the results are satisfactory.

A third modification gives more satisfactory results. The method of treatment is the same as the last mentioned, except that the oxide obtained from the ignition of the carbonate is ignited in a stream of oxygen until no further increase in weight results.

In a former paper from this laboratory‡ one of us made use of the carbonate method for the determination of cadmium after having separated that metal from copper. The filtration was made on asbestos in a Gooch crucible and the results were most satisfactory. The object of the work to be described is to show that when the carbonate is filtered upon an asbestos felt previously ignited the dangers of reduction are obviated and the carbonate process is both simplified and placed among good analytical methods. The solution used for the work was one of cadmium sulphate, and the standard was determined by evaporating measured and weighed portions to dryness in the

\* Jour. Sci. Chem. Industry, vol. xiii, 211.

† Muspratt's theory is that in the ignition of the carbonate the sulphate is dissociated, while the ignition of the nitrate does not effect this result.

‡ Browning, this Journal, vol. xlv, 280.

presence of a few drops of sulphuric acid, igniting at low redness, and weighing as the anhydrous sulphate. The average of several closely agreeing results was taken as the standard. Measured and weighed portions of this solution were diluted to about 300 cm<sup>3</sup> with hot water and a solution of potassium carbonate, 10 per cent, added drop by drop with constant stirring until no further precipitate was obtained. The precipitate was then boiled for about fifteen minutes, when it became granular and settled quickly. It was then filtered upon asbestos, washed thoroughly, dried, and ignited at red heat until a constant weight was obtained. In several instances the weighed oxide was treated with a drop of nitric acid, again ignited and weighed, but in no case was there a perceptible change in weight. In the following table the results are tabulated.

| No.  | CdO taken.<br>gram. | CdO found.<br>gram. | Error.<br>gram. |
|------|---------------------|---------------------|-----------------|
| (1)  | 0·1140              | 0·1143              | 0·0003 +        |
| (2)  | 0·1142              | 0·1137              | 0·0005 —        |
| (3)  | 0·1141              | 0·1148              | 0·0007 +        |
| (4)  | 0·1141              | 0·1148              | 0·0007 +        |
| (5)  | 0·1142              | 0·1146              | 0·0004 +        |
| (6)  | 0·1143              | 0·1147              | 0·0004 +        |
| (7)  | 0·1143              | 0·1144              | 0·0001 +        |
| (8)  | 0·1139              | 0·1146              | 0·0007 +        |
| (9)  | 0·1270              | 0·1272              | 0·0002 +        |
| (10) | 0·1279              | 0·1283              | 0·0004 +        |
| (11) | 0·1272              | 0·1281              | 0·0009 +        |
| (12) | 0·1278              | 0·1281              | 0·0003 +        |
| (13) | 0·2556              | 0·2561              | 0·0005 +        |
| (14) | 0·2550              | 0·2547              | 0·0003 —        |
| (15) | 0·1272              | 0·1279              | 0·0007 +        |
| (16) | 0·1281              | 0·1288              | 0·0007 +        |
| (17) | 0·1274              | 0·1278              | 0·0004 +        |
| (18) | 0·1284              | 0·1290              | 0·0006 +        |
| (19) | 0·1271              | 0·1277              | 0·0006 +        |
| (20) | 0·1278              | 0·1285              | 0·0007 +        |
| (21) | 0·2555              | 0·2555              | 0·0000 ±        |

As will be noticed, the results show a plus error which might naturally be due to a slight inclusion of the alkali carbonate. To test the truth of this hypothesis, a portion of the oxide which gave a plus error of 0·0007 gram. was dissolved and tested for potassium by the perchloric acid method\* and an amount of that element was found equal to 0·0006 gram. of the carbonate. Another portion of the oxide which showed no error was similarly treated and only 0·0002 gram. on the carbonate was found. The results show, as we think, that the carbonate method can be successfully applied to the quantitative estimation of cadmium without recourse to the tedious process of manipulation recommended by Muspratt.

June, 1896.

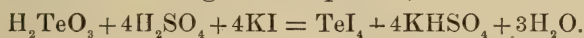
\* Kreider, this Journal, vol. xlix, 443.



ART. XXXVIII.—*The Determination of Tellurium by Precipitation as the Iodide*; by F. A. GOOCH and W. C. MORGAN.

[Contributions from the Kent Chemical Laboratory of Yale University.—LVIII.]

It was known to Berzelius that hydriodic acid and tellurous acid interact with the formation of tellurium tetraiodide, which is converted by water into an oxyiodide and by excess of an alkaline iodide into a soluble double salt. Wheeler\* has shown that the double salt which is formed when tellurous iodide is boiled in a strong solution of potassium iodide in dilute hydriodic acid is definite and has the constitution represented by the formula  $2\text{KI} \cdot \text{TeI}_4 \cdot 2\text{H}_2\text{O}$ . We have observed, however, that when potassium iodide is added to a cold solution of tellurous acid containing at least one-fourth of its volume of strong sulphuric acid, no tendency toward the formation of a double salt becomes apparent until the potassium iodide amounts to more than enough to convert all the tellurous acid present into the tetraiodide according to the equation,



The tellurium tetraiodide which is thus formed is extremely insoluble in sulphuric acid of the strength mentioned, though soluble in excess of potassium iodide, and acted upon by water with the formation of tellurium oxyiodide and hydriodic acid. It is produced at first in the condition of a finely divided dark brown precipitate which upon agitation of the liquid containing it gathers in curdy masses and settles, leaving the supernatant liquid clear. By taking advantage of this tendency to curd it is possible to determine without great difficulty the exact point during the gradual addition of potassium iodide when the precipitation of the tellurium iodide is complete, and we have been able to found upon this property a very simple titrimetric method for the direct determination of small amounts of tellurium.

In our test experiments we used tellurium dioxide prepared by oxidizing presumably pure tellurium with nitric acid and igniting the residue at a low red heat. Weighed amounts of the oxide thus prepared were dissolved in Erlenmeyer beakers in a very little of a strong solution of potassium hydroxide, and dilute sulphuric acid was added carefully until the tellurous acid which was precipitated upon the neutralization of the alkaline hydroxide was just redissolved. To this solution sulphuric acid of half-strength was added in such amount that the solution finally obtained, after adding the aqueous solution of potassium iodide subsequently, should still contain at least

\* This Journal, xlv, 267.

one-fourth of its volume of strong sulphuric acid. The Erlenmeyer beaker was placed upon a pane of window glass supported upon strips of wood about 1<sup>cm</sup> above the level of the work table, which was covered with white paper. A solution of approximately decinormal potassium iodide free from iodate and carefully standardized in terms of iodine by a method described in a former paper from this laboratory\* was introduced gradually from a burette into the middle of the Erlenmeyer beaker. As the drops of the potassium iodide touched the liquid the precipitation formed at the center and traveled in rings toward the outer walls of the beaker. When the liquid became so opaque that the effect of the potassium iodide was distinguished with difficulty, the beaker was rotated and the curded precipitate permitted to settle, and then the process of titration was continued as before. We experimented with amounts of tellurium dioxide varying from approximately 0.025 grm. to 0.1 grm., the latter quantity being as large as can be handled with accuracy without intermediate removal of the precipitate by filtration. With an Erlenmeyer beaker 10<sup>cm</sup> in diameter across the bottom and a final volume of liquid amounting to not more than 100 cm<sup>3</sup>, we were able to follow the precipitation most easily.

The results of a series of determinations made according to the method described and recorded in the following table are closely accordant, and, in close agreement with the theory of the process if the atomic weight of the tellurium which we used is taken as 127. We feel justified in taking this number as the atomic weight of our tellurium, because the mean result of twelve oxidations by standard potassium permanganate of tellurium dioxide, prepared similarly to that which we used and from the same lot of material, and the mean result of twelve reductions by hydrobromic acid of the telluric acid thus produced,† point to this figure.

| Final<br>volume.<br>cm <sup>3</sup> | Strongest<br>H <sub>2</sub> SO <sub>4</sub> present.<br>cm <sup>3</sup> | Iodine value<br>of KI used.<br>grm. | TeO <sub>2</sub> taken.<br>grm. | TeO <sub>2</sub> found.<br>grm. | Error.<br>grm. |
|-------------------------------------|---|-------------------------------------|---------------------------------|---------------------------------|----------------|
| 50                                  | 17  | 0.0706                              | 0.0223                          | 0.0221                          | 0.0002—        |
| "                                   | "   | 0.0764                              | 0.0244                          | 0.0239                          | 0.0005—        |
| "                                   | "   | 0.1591                              | 0.0496                          | 0.0499                          | 0.0003+        |
| 60                                  | "   | 0.1655                              | 0.0517                          | 0.0519                          | 0.0002+        |
| "                                   | "   | 0.1578                              | 0.0498                          | 0.0494                          | 0.0004—        |
| 80                                  | 30  | 0.1591                              | 0.0498                          | 0.0499                          | 0.0001+        |
| 100                                 | "   | 0.3179                              | 0.1001                          | 0.0997                          | 0.0004—        |
| "                                   | "   | 0.3186                              | 0.1008                          | 0.0999                          | 0.0009—        |
| "                                   | "   | 0.3208                              | 0.1011                          | 0.1005                          | 0.0006—        |
| "                                   | "   | 0.3208                              | 0.1010                          | 0.1005                          | 0.0005—        |

From these results it is obvious that the method, which is very rapid, is accurate.

\* This Journal, xxxix, 188; xlv, 334.

† Ibid., xlviii, 377 and 378.

ART. XXXIX.—*Notes on some Mesozoic Plants from near Oroville, California*; by WM. M. FONTAINE.

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DURING the season of 1894, Mr. T. W. Stanton made a small collection of fossil plants from near the Banner Mine in the vicinity of Oroville, California. They were sent to Mr. Lester F. Ward and by him submitted to me for determination. As the plants indicated an interesting flora, not hitherto known in the Mesozoic formations of America, suggesting, possibly, the existence of true Jurassic plants in the United States, Mr. Ward visited the locality in September in 1895, for the express purpose of making, if possible, additional collections. He was so fortunate as to find, in the same vicinity, exposures of the strata, unknown to Mr. Stanton, that were rich in fossils. Mr. Stanton's imperfect collection left the age of the formation yielding the plants in considerable doubt, which the larger one of Mr. Ward with its better preserved impressions served in large measure to remove. Mr. Ward's specimens also were submitted to me, and it is the object of this paper to briefly give some of the results obtained from the study of all the material now in hand from Oroville.

In order that the reader may have some idea of the occurrence of the fossils, it will be necessary to give a few preliminary statements regarding the geology of the region.

Mr. Ward collected from four localities, all in the immediate vicinity of the Banner Mine, and in these are included those that afforded the plants of Mr. Stanton. The plants were all found on the same geological horizon. As Mr. Ward informs me, the strata yielding the plants occur in a narrow belt, a few hundred yards wide, with a dip of 70°–80°. They resemble, lithologically, the Jurassic Mariposa Slates, but, as they have hitherto yielded no fossils, and are connected stratigraphically with no known formation, their age is, as yet, not determined. Mr. W. H. Turner in a paper, "On the Age and Succession of the Igneous Rocks of the Sierra Nevada," published in the *Journal of Geology*, vol. iii, No. 4, May–June, 1895, p. 394, in speaking of the eruptive rocks of the Smartsville area, says, "These rocks, largely augite porphyries and their tuffs, are presumed to have covered, as with a mantle, the underlying Paleozoic formations. There are some streaks of slate among the eruptive masses, but these have not, in the Smartville area, afforded any fossils. However, during the past season, in the northern extension of the same area, in a belt of clay slate interbedded with augite breccia and tuff, fossil plants were collected by T. W. Stanton. The exact locality is, by the stage



road, south of the Oroville Table Mountain, near the Banner gold quartz mine."

These are the plants referred to in the beginning of this paper.

Mr. Ward's collection, although much larger than that of Mr. Stanton, and containing better preserved specimens, still shows very imperfectly the character of a number of plants. Enough is made known, however, to prove that they are distinct species, but either the amount of material, or the state of preservation, does not suffice to fix with precision the identity or the affinity of the form. It is for this reason that the location of certain plants in the following list is left in doubt. The list below gives the plants made out with more or less definiteness from the Oroville beds.

*List of Plants from the Oroville beds.*

1. *Chadophlebis*\* *spectabilis*, Heer.
2.       "       *argutulus*, "
3.       "       *Whitbiensis tenuis*, var. *a*, Heer, species.
4.       "       *densifolia*, n. sp.
5.       "       *Indica* ?, Old and Mor.
6. *Adiantites* *Orovillensis*, n. sp.
7. *Thyrsopteris* *Maakiana* ?, Heer.
8. *Pecopteris* *gleichenoides* ?, Old. and Mor.
9. *Tæniopteris* *Orovillensis*, n. sp.
10. *Angiopteridium* *Californicum*, n. sp.
11. *Sagenopteris* *rhoifolia* ?, Presl.
12. *Macrotæniopteris* *Californica*, n. sp.
13.       "       *nervosa*, n. sp.
14. *Pterophyllum* *Rajmahalense* ?, Mor.
15. *Ctenis* *grandifolia*, n. sp.
16.       "       *auriculata*, "
17.       "       *Orovillensis*, "
18. *Ctenophyllum* *Wardii*, n. sp.
19.       "       *angustifolium*, n. sp.
20.       "       *grandifolium*, var. *Storrsii*, n. var.
21.       "       *densifolium*, n. sp.
22. *Podozamites* *lanceolatus*, [L. and H. spec.] Schimp.
23.       "       "       var. *latifolius*, Heer, var.
24. *Pinus* *Nordenskiöldi* ?, Heer.
25. *Pagiophyllum* *Williamsoni*, [L. and H. spec.] Heer.
26. *Carpolithus* *Storrsii*, n. sp.
27. Undetermined Cone.

Whatever may be the true place of these 27 forms, they are all different. The flora does not seem to have had great variety, but judging from the number of specimens, such

\*I prefer the name "*Cladophlebis*" for these plants, which Heer regards as *Asplenium*.

plants as *Tæniopteris Orovillensis*, *Podozamites lanceolatus*, and *Ctenophyllum densifolium*, were very common, *Ctenis auriculata*, *C. grandifolia*, *Ctenophyllum grandifolium*, var. *Storrsii*, were less abundant, but still common. The rest occur more rarely, and some, such as *Adiantites Orovillensis*, are found only in a single specimen. The plants, considered in their identical and most nearly related forms, range in time from the Rhetic, or uppermost Trias, to the Potomac. No plant is identical with any belonging to the Potomac, and only a single one, *Ctenophyllum Wardii*, has relationship with a Potomac form, viz.: *Ctenophyllum latifolium*, Font. There can then be no doubt that the age is not Potomac. The following plants do not show a sufficiently near relationship with known species to indicate any particular age: *Adiantites Orovillensis*, *Macrotæniopteris nervosa*, *Ctenis grandifolia*, *C. auriculata*, *C. Orovillensis*. Compared with uppermost Trias and Rhetic plants, we find, in the Oroville flora, one whose identity is doubtful, viz.: *Sagenopteris rhoifolia*, and four which show pretty close relationship. They are as follows: *Ctenophyllum angustifolium*, which is much like *C. Braunianum*; *C. densifolium*, *C. grandifolium*, var. *Storrsii*; which are near, the latter especially, *C. grandifolium* of the older Mesozoic of Virginia; *Tæniopteris Orovillensis*; which is much like *T. tenuinervis*, of the Infra-Lias (Rhetic) of France. As most of these are common plants in the Oroville flora, there is in it a pretty strong element indicating, by relationship not identity, an age near the beginning of the Lias. If we make a distinction between the members of the Jurassic as Lias and Oolite, and if we admit, as we probably should, the correctness of Feistmantel's contention, that the age of the Rajmahal Series is Liassic, we find a strong element in the Oroville flora pointing to both a Liassic and Oolitic age for it.

Three of the plants are doubtfully identified with Liassic ones, viz.: *Pecopteris gleichenoides*?, *Cladophlebis Indica*?, and *Pterophyllum Rajmahalense*?, and three show affinities with forms of that age. These are *Cladophlebis densifolia*, *Angiopteridium Californicum*, *Macrotæniopteris Californica*; six of the plants occur in the lower Oolite, and two are identified doubtfully with lower Oolite species. The six Oolite forms are *Cladophlebis spectabilis*, *C. argutulus*, *C. Whitiensis tenuis*, var. *a*, *Podozamites lanceolatus*, *P. lanceolatus latifolius*, *Pagiophyllum Williamsoni*. The two doubtful forms are: *Thyrsopteris Maakiana* and *Pinus Nordenskiöldi*.

From this it will be seen that the evidence that the age is Jurassic, is stronger than that for any other, and as the Oolitic plants predominate, we may assume with considerable probability, that it is rather late Jurassic, being about that of the lower Oolite.

ART. XL.—*On a New Method for Reading Deflections of Galvanometers*; by C. B. RICE.

A METHOD of reading deflections of galvanometer needles and analogous apparatus has been recently devised in this laboratory by Professor C. S. Hastings, which, since it proves to have considerable value, he has given me the opportunity to describe.

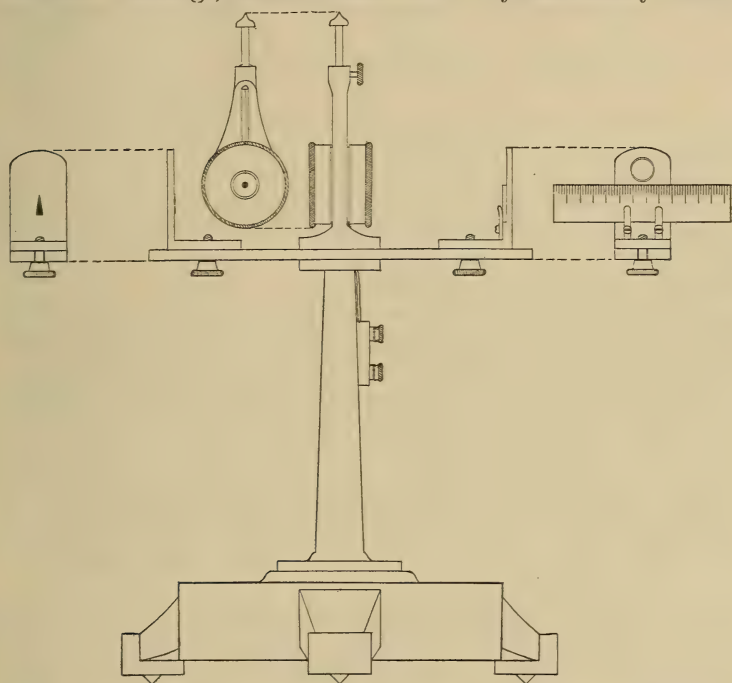
There are two types of sensitive galvanometers in general use, namely, those in which the deflections of the suspended system are determined by the motion of an image of a luminous source on a scale, and those in which the deflections are measured by telescope and scale after the method first introduced by Gauss and Weber. The Thomson galvanometers are the familiar examples of the first, and the Wiedemann of the second.

Each of these has certain inconveniences. That of Thomson, although an exceedingly sensitive galvanometer, requires a darkened room and a lamp, with somewhat inaccurate determination of the angle of deflection. It is also rather too delicate to put into the care of the untrained student. Wiedemann's is much better suited for ordinary laboratory work. Here less sensitiveness is compensated by much greater precision of angle measure, while its construction renders it safe to put the instrument into comparatively unskillful hands. A much wider range of sensitiveness and of damping is readily secured in this form than in Thomson's. It has, however, the inconvenience of requiring the rather expensive accessory of a telescope and scale and also of demanding a large amount of space in its employment. These disadvantages are not of such great moment in most cases, perhaps, to forbid its use, and in our laboratory we found such instruments, well constructed of metal throughout, thoroughly satisfactory until continuous disturbances of magnetic field in the region were brought about by the construction of an electric road. Experience showed that the sensitiveness was thus reduced to about one-tenth its former value. D'Arsonval galvanometers of course eliminated this difficulty, but they too have their inconveniences and limitations.

If the linear dimensions of a Wiedemann's galvanometer were sufficiently reduced, say  $n$ -fold, the sensitiveness would be increased, while the accuracy of determination of duration would be decreased in the same ratio, since the apertures of the optical apparatus are thus reduced. If this were carried far enough, the aperture of the telescope would be reduced to that of the pupil of the eye and might be dispensed with



without loss. On the other hand, the disturbances of the field being no greater than before would now have  $n$ -fold less effect. Hence, in an irregularly variable field such an instrument would be  $n$ -times as accurate. In practice the gain is really much greater than this because of the much reduced period of the needle. These disturbances must be regarded as perfectly irregular in the larger instrument, but may here be treated as sudden occasional changes separated by periods of quiescence. A galvanometer constructed on this theory, as developed by Professor Hastings, has been tried with very satisfactory results.



The magnet is a circular steel disk of  $1^{\text{cm}}$  diameter polished on both sides for convenience, serving as a mirror, hung between two coils of wire with a silk suspension of about  $5^{\text{cm}}$ . The coils are of number 36 wire with an outside diameter of  $2.5^{\text{cm}}$  and have a resistance each of six ohms. The brass covers which fit over the coils are provided with openings closed by glass so that there is a clear view of both faces of the magnet, while air currents are excluded. A small aperture of  $1.4^{\text{mm}}$  diameter in the center of the steel mirror permits a view of objects beyond, which lie sufficiently near the axis of the instrument. Facing the coil and the magnet within, but at a trifle higher level, is placed a small lens at a distance adjustable from 5 to  $7^{\text{cm}}$  from the magnet. On the opposite side, at a similar adjustable distance from the mirror, is fixed a fine

point, preferably of some dark material with a white background. Directly under the lens is a small scale. The image of this scale as formed by the mirror is seen superimposed upon the image of the fixed point as seen through the aperture in the mirror, and any change in the angular position of the mirror causes a relative shifting of these two images, which, under proper adjustment, are in the same plane and are, therefore, perfectly free from errors of parallax. The use of the lens serves the double purpose of reducing the linear dimensions of the apparatus and of giving such precision to the ocular accommodation that the edges of the hole in the magnet as well as the fixed image of the scale due to the glass windows are so far out of focus as to be quite invisible. When the lens, point and small scale are once adjusted the instrument is ready for use at any time with no further attention. If the support be moderately level no leveling screws are necessary.

With this galvanometer a potential of  $\frac{1}{100.000}$  of a volt is readily detected by repeated closing of the circuit—a sensitiveness which is more than sufficient for a large part of the elementary work of the laboratory.

The simplicity and cheapness of this type of galvanometer make it very desirable, while its lack of delicacy is of considerable moment where the care of it falls upon the novice.

There seems to be no reason why this method for reading deflections should not be used with all other galvanometers as a substitute for the telescope and long scale. The angular measures are read with great accuracy and with much greater precision than with the lamp and scale of Thomson's method. The small scale used in this connection should be divided into half millimeters, for the reading is made with clearness to tenths of such an interval.

The instrument figured is one of those constructed at this laboratory and must be looked upon simply as an example of a convenient, moderately sensitive, but widely useful form. The two coils are separated by a copper ring about 3<sup>mm</sup> in thickness which produces a certain damping, although the galvanometer serves very well for ballistic use. Notwithstanding the moderate damping, the actual time required to secure a succession of readings is certainly not greater than is found necessary in using a Wiedemann aperiodic galvanometer, because the period is so greatly reduced. In an astatic system with long period more effective damping would doubtless be desirable, but in such a case there would be no difficulty in employing Thomson's ingenious air damping.

It is obvious that a needle constructed of small steel magnets cemented to silvered glass, the silver being removed from a small portion, might replace, and in some cases advantageously, our steel mirror.

Physical Laboratory, Sheffield Scientific School.

ART. XLI.—On Crystal Measurement by means of Angular Coördinates and on the Use of the Goniometer with two Circles,\* by CHARLES PALACHE.

THE methods of crystal measurement in general use at the present time are based on the determination of the *interfacial angles* from which are deduced the system and elements of the crystal and the symbols of the forms.

There is, however, another system of measurement which leads to these results more simply and more directly. We may term it the measurement of crystals by determination of *angular coördinates*.

In the familiar spherical projection the crystal faces are represented by the points of intersection of the face-normals with the surface of a sphere described about the crystal center. The relations of these points upon the sphere are known, if we determine the angular distances between them (measurement of interfacial angles) or if we determine the position of each one with reference to a set of coördinates (measurement by angular coördinates). These operations are strictly analogous to well known geographical operations; the first is comparable to triangulation, or the measurement of angular distances between points on the earth's surface; the second is like the determination of localities by latitude and longitude—that is, by reference to an equator and a meridian as fixed coördinates. The latter operations are so nearly alike that it is found convenient to retain the geographical terms for the crystallographic coördinates, and we accordingly speak of the equator and meridian of the crystal.

Any great circle of the sphere of projection may be taken as equator and the pole will lie at a distance of  $90^\circ$  therefrom. Any great circle at right angles to the equator may be taken as first meridian. In practice the choice of coördinates is limited to a few cases.

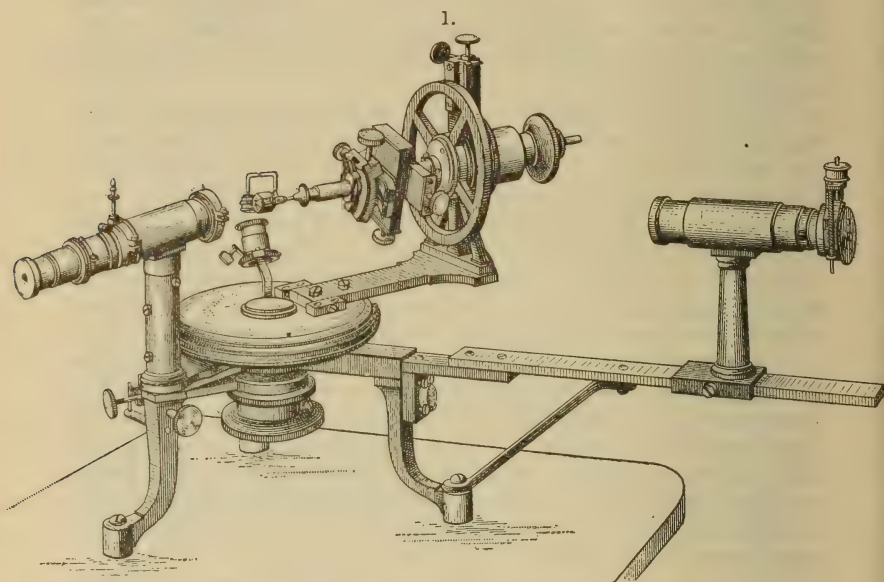
The means of applying this principle to crystal measurement is found in the *goniometer with two circles*† of which fig. 1 is

\* A better name for this instrument than the literal translation of its German title (zweikreisiges goniometer), given above, is highly desirable but has not occurred to the writer. Neither of the names employed by Fedorof "Universal-(Theodolith-) goniometer" seems fully or correctly descriptive. Some such term as dicircle or biaxial goniometer may be found to be as simply descriptive as any.

† The instrument here shown is the original one constructed for Prof. V. Goldschmidt. Minor changes have since been introduced into its construction, which, however, do not affect its principle. It, as well as the other instruments to be described, is made by the mechanic P. Stoë, Jubiläumsplatz 70, Heidelberg, and the writer can testify to the careful and thorough construction. The same



an illustration. Its construction is best explained by reference to the outline view and plan, figs. 2 and 3. H is the horizontal circle revolving about the axis  $h$ , graduated and provided with fine adjustment and vernier. Rigidly attached to H by an arm and at right angles to it is the vertical circle V revolving about the axis  $v$  and also graduated and provided with fine adjustment. The axis  $v$  supports an adjusting device such as is found on the ordinary goniometer and upon it the crystal is mounted by means of a carrier  $m$  capable of independent adjustment.\*



The collimator C and telescope F are horizontal; they may be moved relative to each other and the angle between them measured.

By revolution of V (from an arbitrary zero through an angle  $\phi$ ) each face of the crystal may be brought perpendicular to H. By revolution of H (through angle  $\rho$  from arbitrary zero) the face may be brought perpendicular to S, the bisectrix of the angle CkF, also and will then reflect the signal upon the crosshairs of the telescope. The angles  $\phi$  and  $\rho$ , read upon the vertical and horizontal verniers respectively, determine the

principle and a similar construction are employed in the Universal (Theodolith-) goniometer (Zeitschr. f. Kryst., xxi, 1893, p. 514) devised by Fedorof and constructed by Fuess of Berlin and the instrument of Czapski (Zeitschr. f. Instrumentenkunde, 1893, i) is also similar.

\* See description of this convenient device (Krystallträger) in Zeitschr. f. Kryst., xx, 1892, p. 344; idem xxv, 1896, p. 541.



the face is centered.  $H$  is now brought to the reading  $h_0$  and the reflection from  $f$  centered on the crosshairs by use of the adjusting tables. When properly adjusted, that is when parallel to  $V$ , the reflected signal should remain stationary on the crosshairs during a revolution of  $V$ .

Case II. The pole face ( $f$ ) defined by a zone perpendicular to it (prism zone in general).

An edge of the prism zone is centered and adjusted to the horizontal crosshair.  $H$  is clamped at  $h_0 + 90^\circ$  and the reflections from two adjacent faces of the zone are brought to the center of the crosshairs by means of adjusting tables.  $H$  is then loosened, the edge again centered and the whole repeated as often as necessary. Other faces of the zone are then examined and if necessary the adjustment bettered. When the prism zone is thus adjusted at  $h_0 + 90^\circ$ ,  $f$ , the pole face, is at  $h_0$  and if present its reflection should be on the crosshairs when  $H$  is brought to  $h_0$ . This case is important since the plane at right angles to the prism zone is the normal plane of projection in all systems and this position gives simple and direct results in the calculation. The prism zone is rarely lacking entirely and even when its faces are poor or striated its correct adjustment is possible.

For adjustment in the many other cases that may arise reference is made to the original papers.\* The crystal once adjusted, each face is brought to reflection by movements of  $H$  and  $V$  and the angles  $\phi$  and  $\rho$  observed. If both ends of the crystal are developed, it is inverted after measurement of one end, the same zone being made equatorial and the same meridian being used. If the readings in the new position be  $\phi' \rho'$ , then

$$\begin{aligned} 180^\circ - \rho' &= \rho. \\ -\phi' &= \phi. \end{aligned}$$

The value  $\phi_0 = h_0$  is subtracted from all the values found for  $\phi$ . The value  $\rho_0 = v_0$  (for the first meridian) is similarly subtracted from all the values for  $\rho$  and the resulting values,  $\phi - \phi_0 = \varphi_1$ ,  $\rho - \rho_0 = \rho_1$  are the angular coördinates of the faces.

The angles thus determined for each face are evidently quite independent of any other face and give an absolute picture of the crystal as it is, quite free from the approximations and averages introduced when the measurement is by zones as is now usual. If desired they give likewise the interfacial angles and (what cannot be measured by the other method) the angles of the zones or edges.

\*V. Goldschmidt, Goniometer mit zwei Kreisen, Zeitschr. für Kryst., **xxi**, 1893, p. 215. Polarstellen am zweikreisigen Goniometer, idem, **xxiv**, 1895, pp. 610-613.



The discussion of the results may proceed directly, but is simplified and hastened by the use of the graphical method. This is based upon the *gnomonic projection*. In this projection the crystal faces are represented by the points of intersection of the face-normals with a plane tangent to the sphere of projection and preferably normal to the chief zone of the crystal. Thus in general the plane of projection is chosen parallel to the vertical circle V of the goniometer, that is, normal to the prism zone of the crystal as usually mounted.

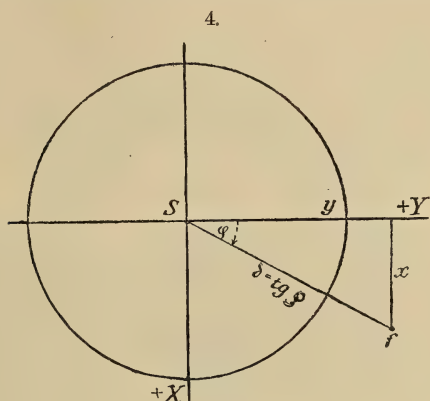


Figure 4 shows a gnomonic projection.  $S$  is the projection of the pole face or the face normal to the prism zone. The circle described about  $s$  as center (Grundkreis) has a radius,  $r$ , equal to the distance from the crystal center to the plane of projection.  $X$  and  $Y$  are the projections of the axes  $a$  and  $b$ . If  $r = 1$  and  $SY$  is taken as first meridian, then the position of a face,  $f$ , is given directly in the projection by its angular (polar) coördinates  $\delta = \text{tg } \phi$  and  $\phi$ . Or it may be located by the rectangular coördinates derived from the first,

$$x = \sin \phi \text{ tg } \rho.$$

$$y = \cos \phi \text{ tg } \rho.$$

The values for  $x$  and  $y$  may be calculated for each face from its  $\phi_1$  and  $\rho_1$  and plotted on ruled paper very rapidly, and this projection gives a direct picture of the crystal showing its degree of symmetry and the relations of its faces. Both measurement and projection are the same for all systems, and, if unknown before, the symmetry of the crystal may be found from the projection.

If the distance from crystal center to plane of projection ( $= r$ ) be taken as unity, and axis  $c$  equal to  $r$ , then in the rectangular systems the values of  $x$  and  $y$  for the unit form which are measured in the directions of the  $a$  and  $b$  axes respectively,

give directly the axial values  $a:b:c(=1)$ , which are readily transformed to the usual form,  $a:b(=1):c$  by interchange of axes.

In the monoclinic system the additional elemental value, angle  $\beta$ , is found directly by the angular distance from the pole S to the projection of the basal plane.

In like manner in the triclinic system the angles  $\alpha, \beta, \gamma$  are found in the projection if the pinacoidal planes are present, or by calculation if sufficient values are given by the measurement.

The unit form being chosen in the projection, the symbols of the other forms may be read off directly by measurement of their coördinates in terms of the axial units, and the symbols so obtained are the same as the Miller index symbols except that the third index is always made unity.

$$\left\{ \frac{h}{l} \cdot \frac{k}{l} \cdot \frac{l}{l} (=1) \right\}$$

The zonal relations of the faces are also well exhibited in the gnomonic projection, tautozonal planes being projected in a straight line. A disadvantage of this projection consists in the fact that the prism faces, being normal to the plane of projection, are projected to infinity ( $\rho = 90, d = \tan \rho = \infty$ ). But their relative positions are given adequately by their angles  $\phi$ .

When the projection is carried out with care the results obtained for axial elements by measurements taken from it are very accurate, often agreeing with calculated results to the second or third decimal place.

The calculations are simple and may be carried on simultaneously with the projection, the two serving as mutual checks against errors. The form of the measurements enables all good faces of the crystal to be employed in the final determination of the crystal elements, a notable advantage over the older method which is dependent for these values on the perfection of one or two zones.

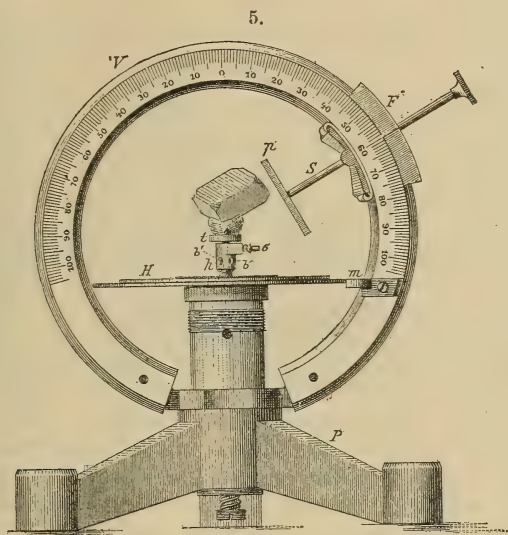
For an example of the form in which the discussion and computation of measurements taken on the goniometer with two circles may be best carried out, the reader is referred to a paper by Prof. Goldschmidt, *Phosgenit von Monteponi*, *Zeit. für Kryst.*, xxi, 1893, p. 321. The compactness and simplicity of the whole is there made manifest. The use of spherical trigonometry is dispensed with and the whole computation is constantly before the eye, so that the detection of errors, if such occur, is comparatively easy.

The gnomonic projection serves further as a basis for the construction of other projections. By a simple construction\*

\* Goldschmidt, *Ueber Projection und graphische Krystallberechnung*, Berlin, 1887, p. 38.

the stereographic projection may be derived from it with an accuracy not attainable by direct construction. The orthographic and clinographic projections may also be directly obtained from the gnomonic projection,\* whereby the construction of the linear projection and the projection of axes is dispensed with.

Twin crystals are treated exactly as are simple ones both in measurement and projection, the position of the twinning plane, if not already known, being determinable from the projection and the perspective figure being derived as in the case of single individuals.



This principle of crystal measurement has also been applied in a *contact goniometer*. This instrument is shown in fig. 5. The crystal is borne on the horizontal circle which takes the place of the vertical circle in the reflecting goniometer. The horizontal circle H revolves with the crystal and its position is read from the graduated edge.

The vertical circle V is fixed at right angles to H and in the plane of its center. It is graduated from the top in either direction from 0° to 100°. On V slides a closely-fitting carrier which holds a steel rod, S, arranged to slide in and out in a direction radial to V. On its end is a plate p, normal to its extension, with which contact is made with the surface to be measured.

The crystal is mounted on a support which is attached to H

\* Idem, p. 82, and Ueber Krystallzeichnen, Zeitschr. f. Kryst., xix, 1891, p. 352.



by a tightly-fitting ball-and-socket joint, adjustable by a key which fits in two holes bored in the stem at right angles to each other. The crystal is affixed to the support as nearly as may be in the desired position. The prism zone, if present, is preferably placed perpendicular to H or the basal plane (pole face) parallel to H. If the basal plane is present, the carrier with S is placed at  $0^\circ$  and the plate  $p$  brought nearly in contact with the crystal face. The crystal is then tipped gently by means of the key and ball-and-socket joint first in one direction and then at  $90^\circ$  to the first, until the face is parallel with  $p$ , that is normal to S.

If the prism zone is to be used in orienting the crystal, the rod is set at  $90^\circ$  and two of the prism faces successively brought parallel to  $p$ . In other cases the procedure is similar to that for the reflecting goniometer,\* V and H in the two instruments being always interchanged. The crystal being oriented, the measurement is effected by bringing each face parallel to  $p$  by movements of H and of the carrier on V. Readings are taken on each circle, that on H giving  $\phi_1 = \phi - \phi_0$  where  $\phi_0$  is the reading for the first meridian and that on V giving directly the polarelevation  $\rho_1$ . The measurements are discussed in the same manner as those on the reflecting instrument. Readings are exact to within  $\frac{1}{2}^\circ$ , depending on the size and character of the faces and the practice of the observer.

The instrument is also useful in demonstrating the principle of the method, its relation to the geographical and astronomical methods of measurements, and especially the relations existing between crystal faces, their normals and their projections either in stereographic or gnomonic projection.†

A further extension and application of this method of crystal measurement is found in the latest product of Prof. Goldschmidt's inventive genius—the *projection goniometer*. The purpose of this instrument is to construct a gnomonic projection directly from the crystal without either measurement of angles or calculation being necessary. Angular measurements may, however, be taken at the same time, and the instrument thus in a measure supplies the place of the reflecting goniometer.

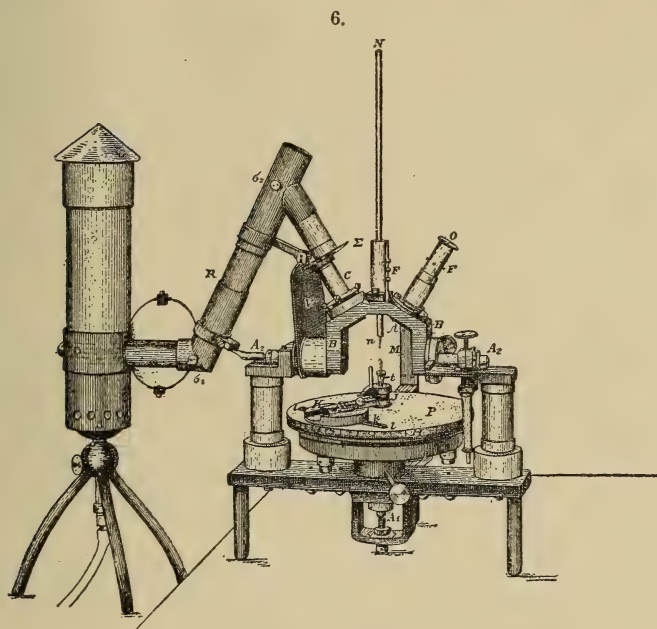
Fig. 6 shows the instrument as first constructed. The horizontal circle H turning about the axis  $A_1$  has a plane surface of brass or glass. A paper is fastened upon it to receive the points of projection. H is graduated with readings to  $1'$ .

Resting freely on H is the carrier S, upon which is placed the crystal. S consists of a heavy base K; of a guide  $\mathcal{U}$ , which rests against two pegs in H and serves to keep the carrier in a

\* Polarstellen am zweikreis. Goniometer, Zeitschr. für Kryst, 1895, xxiv, p. 610.

† For further details concerning the use of this instrument see Anlegegoniometer mit zwei Kreisen, V. Goldschmidt, Zeitschr. für Kryst, xxv, 1895, p. 321.

certain part of the horizontal circle; and of the centering and adjusting devices. The centering device enables the movement of the crystal in three rectangular directions, by means of which it may be brought into the intersection of the two axes  $A_1$  and  $A_2$ . The adjusting device is a ball-and-socket joint like that of the contact goniometer, or an ordinary tipping table.



The vertical circle is represented by the bent arm B revolving about the axis  $A_2$  in a plane perpendicular to H. It can be clamped at any point and carries a graduated segment of a circle, V. The arm B carries the collimator C and the telescope F; and between them, in their plane and bisecting their angle CF, a rod N with needle point  $n$ . N can be shoved down in its bearing until the point reaches the paper, where it marks the point of projection.

The light is carried to the collimator from the lamp\* by means of the broken tube R, in which are two mirrors; in all positions of the arm B the light follows the collimator. The needle N moves with the arm B about the axis  $A_2$  and in a plane normal to H. Its arc is  $90^\circ$ , from vertical to horizontal, and the point is always directed to the same side. On this

\* For the construction of this lamp see Zeitschr. für Kryst., 1894, xxii, p. 149. It employs the Welsbach light, gives an intense light for the signal and has a side opening with mirror which gives light for reading the vernier and entering notes. It is made by P. Stoë.

side at the edge of H is fixed a vertical scale M, which receives projections as of prisms and steep pyramids which would fall outside the paper. By means of a ruler at the foot of M a mark is made on the paper showing the direction of such projections (the meridian).

The use of the instrument is ordered as follows: Paper being mounted on the horizontal circle and the crystal attached to the carriage in as near the desired position as possible, the carriage is brought upon H and the crystal brought to the center of the instrument. The adjustment of the crystal in polar position is similar to the method explained for the other instruments. If the polar face is present, the vertical circle is set at  $0^\circ$  and the crystal tipped by means of the adjusting key until the image reflected from the face is at the crosshairs of the telescope and remains stationary during a revolution of H. If the adjustment is to be made by means of the prism zone, V is clamped at  $90^\circ$  and the adjustment made for two adjacent faces of the zone successively.

The crystal being oriented, V is brought to  $0^\circ$ , the crystal removed on its carriage and the needle is pressed down to mark the projection of the pole on the paper. The needle being withdrawn and the carriage replaced, a new face is brought to reflection by movements of H and V, both are clamped, the crystal removed as before, the point of projection pierced on the paper and readings taken on H and V for  $\phi$  and  $\rho$ . This process is repeated for each face, is rapid and involves no special difficulties.

All the faces having been projected, the paper is removed from the instrument and mounted on a large sheet for the purpose of plotting the points which fell without its surface. The resulting projection is discussed in the same manner as the ordinary gnomonic projection. For further details concerning the use of this novel instrument, the discussion of the resulting projection, and for examples of measurements carried out upon it showing the remarkable accuracy of the results obtained, the reader is referred to the paper by Prof. Goldschmidt. *Ein Projektionsgoniometer*, *Zeit. für Kryst.*, xxv, 1896, p. 538.

It is beyond the scope of this paper to describe the system of form development based on "force symbols," with its new elements and symbols, which has been developed by Prof. Goldschmidt. With the *Index der Krystallformen*, the forthcoming table of angular coördinates (*Winkeltabelle*) for all minerals, and the goniometer with two circles which is its logical outgrowth, it forms a symmetrical system destined to vastly simplify the work of practical crystallography and to increase its scope and accuracy.



ART. XLII.—*Search for Solar X-Rays on Pike's Peak*; by  
FLORIAN CAJORI.

EXPERIMENTS carried on by M. C. Lea\* and others have failed to show the presence of Röntgen rays in solar radiation. If these rays reach us from the sun, their intensity must be exceedingly feeble. The suggestion has been made that Röntgen rays may exist in sun-light, but are absorbed by the earth's atmosphere. The fact that Lenard rays are stopped by only a thin layer of air made it not improbable that Röntgen rays might be stopped by a thick layer of it. On this hypothesis a mountain top is the best locality to examine sun-light for the new rays. The writer determined, moreover, to expose the photographic plate to solar rays, not several hours, but several weeks.

During preliminary experiments made in Colorado Springs, it was found that a sheet of aluminium would allow certain solar rays to pass through. These were not Röntgen rays, for the reason that black paper placed between the aluminium and the photographic plate seemed to cast as deep a shadow as did a strip of iron. A different mode of exposing the plate was necessary and a plan similar to Lea's was finally adopted.

The first 100 leaves of an unbound book were turned over, and a rectangular trough of the dimensions of the photographic plate (7.5 by 13<sup>cm</sup>) cut into the next 55 pages. Seven pages above this trough, thin metallic plates, from 5 to 20<sup>mm</sup> wide, were placed between two leaves and held in position by gumming the two leaves together. Care was taken to let the mucilage dry before shutting the book. After the photographic plate (Seed, 23) was placed in the trough, the book was closed, wrapped in black tissue paper, then in paraffine paper, and finally put into a tin box.

The box was prepared as follows: Its lid was placed externally over its bottom and a rectangular window, 7.5 by 13.5<sup>cm</sup>, cut through them both. Thereupon a sheet of aluminium, 13 by 23<sup>cm</sup>, and .29<sup>mm</sup> thick, was placed between the lid and the bottom, so as to screen the window. The wide margin of the aluminium, lying between the sheets of tin, was united to them above and below by thin layers of bees'-wax. Externally the edges of the rectangular window were covered with sealing-wax, to which a thick layer of paint was finally applied. A new lid was provided for the open side of the box and both lids were soldered on. Prepared in this manner, the box could be left exposed to all kinds of weather without danger that moisture would reach the photographic plate. To touch the

\* This Journal, IV, vol: i, May, 1896, pp. 363, 364.

plate, rays had to penetrate the sheet of aluminium, a few layers of paraffine and black paper, and 100 pages of the book. Röntgen rays of intensity ordinarily met with in the laboratory penetrate at once very much greater thicknesses of these materials.

Through the kindness of Mr. F. Blackmer and Mr. D. Rupp, of Colorado Springs, the box was taken to the summit of Pike's Peak (elevation 14,147 ft.) and fastened by wires upon a roof sloping southward. The box was left in that position from June 27 to August 10. When subjected to the usual process of development, the plate failed to show any action of rays and presented a uniform surface, without traces of shadows from the metallic strips. Another plate, similarly exposed from July 7 to August 28 in Rosamont Park, near Pike's Peak, at an altitude of 9200 ft., gave the same result.

Thus even in high altitudes no evidence of the presence of Röntgen rays in solar radiation was obtained.

Colorado College, Colorado Springs.

ART. XLIII.—*Note on recently discovered Dikes of Alnoite at Manheim, N. Y.*; by C. H. SMYTH, JR.

THE occurrence of alnoite at Manheim, N. Y., is of interest both on account of the rarity of the rock, and because it is one of several rather widely-scattered occurrences of basic intrusions cutting the Paleozoic rocks of Central New York.

When described by the writer,\* some years since, the rock was represented, so far as known, by a single dike, of very limited dimensions. Recent blasting in the stream gorge, a few rods above the old locality, has exposed another dike, and a third one of small size has been found near by. The latter dike is precisely like the small one previously described, but not so well exposed, as it lies in a very irregular fissure, from which it has been deeply weathered out, the resulting excavation being nearly filled with bowlders washed in by the stream.

A similar fissure, but much larger, formerly existed where the blasting has been done, and is now clearly seen to have been formed by the weathering of a dike about six feet in width. The rock of this dike bears a general resemblance to that of the smaller dikes, but shows some decided variations resulting from the greater size of the intrusion. At and near the contact with the surrounding Calciferous, it shows small phenocrysts in a very fine-grained groundmass. Toward the center, however, it becomes quite coarse and inclined to granu-

\* This Journal, III, xliii, p. 322, and xlv, p. 104.

lar, showing an abundance of mica. The structure in these central portions has been considerably modified by shearing, the rock being crushed, slickensided and much altered. Unfortunately, this has rendered it difficult to procure satisfactory material for study from the coarser parts of the rock.

A notable feature of the dike is the presence in it of long, narrow "horses" of the country rock. One of these is fifteen or twenty feet long, about one foot wide, and with tapering ends. These horses affect the dike just as the walls do, rendering the rock fine-grained. The rock of the walls and horses shows very scanty signs of contact metamorphism, consisting of some slight changes of color.

The color of the fresh dike rock is very dark-gray to black; but there is often a tinge of green from alteration and this is sometimes pronounced. Further decomposition breaks the rock down to a sandy clay with scattered flakes of mica. Under the microscope, this clay is seen to consist chiefly of finely-divided mica, with minor magnetite and apatite, the other minerals having disappeared. That such complete alteration and disintegration take place readily is shown by the occurrence of the dikes in deeply excavated trenches. It is also perfectly displayed on the opposite side of the stream, where what is doubtless the continuation of the large dike is shown. It is a vertical band of the clay above described, cutting sharply through the Calciferous, and exposed for a height of about twenty feet. The wall rock is perfectly fresh, but the dike is so thoroughly decomposed that only the scales of mica and an occasional lump of alnoite the size of a walnut show the true origin of the material.

Sections of the rock of the small dike agree perfectly with the original dike, and need no further consideration. The large dike, however, shows decided differences, with one exception, of such a nature as would be expected from its coarser structure.

Sections of specimens taken from near the margins of the dike, or close to the included horses, have a very fine ground-mass, in some cases looking almost like an altered glass. In this are scattered phenocrysts of deep-brown mica and altered olivin. The latter mineral, in these parts of the dike, is usually represented by a semi-opaque, white substance, through which is disseminated a black dust, doubtless magnetite. This method of alteration of olivine seems to be dependent upon proximity to the wall rock, as it does not appear in the central portions of the dike.

Sections from the latter approach a granular structure, and consist chiefly of mica and altered olivine. The structure is not that of a granite-granular or hypidiomorphic rock, as the two chief minerals are quite commonly bounded by their true crystal form. The mica has a deep reddish-brown color, is



strongly pleochroic and in basal sections often has a marked zonal structure. In spite of the fresh look of the rock in hand specimens (which is due to the great abundance of mica), not a grain of unchanged olivine has been found, and the determination of the mineral is based wholly upon the form and composition of the alteration product, and the undoubted presence of olivine in the neighboring dikes. It is now represented by serpentine of deep green color. Less often a phenocryst is clear and colorless, presenting at first glance the appearance of unchanged olivine, but, with crossed nicols, showing aggregate polarization in low tints.

In addition to the two chief constituents, magnetite and apatite are present in some quantity, while perovskite is less abundant. Large amounts of secondary calcite are shown in nearly every section.

The most striking feature of the rock is the scarcity or absence of melilite. In the other two dikes this mineral is abundant, though often greatly altered; but in the large dike it has not been positively identified, although its presence is occasionally indicated by obscure alteration products.

This peculiar fact admits of two explanations. It is possible that, owing to the slow crystallization of the material of the large dike, or to some other variation of conditions, melilite was never formed, its elements entering into other combinations. If this were so, hornblende or pyroxene might be expected in the rock, and none is shown. It is possible, however, that such a mineral is now represented by a part of the serpentinous alteration products.

The second explanation of the absence of melilite ascribes it to the complete removal of the mineral by the processes of alteration. This supposition is in harmony with the well-known susceptibility of the mineral to alteration, which is well shown in the other dikes, where much of the melilite is so altered as to entirely obscure its original properties. Nevertheless, even here, much clearer traces of its form and structure may be seen than in the large dike, where they are usually absent.

Between these two explanations it is impossible to decide with absolute certainty. But in view of the close proximity of the three dikes, the similarity of conditions that must have prevailed during their consolidation, and the identity of all the other minerals, together with the excessive alteration of the large dike, it seems extremely probable that melilite was originally present in the latter. On this ground it is included with the other two dikes under the term *alnoite*.

That still other dikes of a similar character exist in the vicinity can hardly be doubted, but their extreme susceptibility to weathering combines with the extensive covering of glacial material to conceal them from observation.

Hamilton College, Clinton, N. Y., June, 1896.

ART. XLIV.—*The Action of Ferric Chloride on Metallic Gold*; by PARKER C. McILHINEY, Ph.D.

IN the course of a number of experiments on the solubility of gold the action of pure concentrated hydrochloric acid on precipitated gold was tried by placing the two together in glass tubes, which were then sealed up and heated to about  $150^{\circ}$  C. for varying lengths of time. In one of the tubes considerable gold was found to have been dissolved, while in others none was dissolved, and investigation showed that the gold which had gone into solution was contaminated with a trace of iron. The experiment was repeated, using 0.046 gram of the same gold and  $10^{\circ}$  of hydrochloric acid. After heating, the gold was found completely dissolved and on separating the gold from the solution by  $\text{H}_2\text{S}$  and determining the iron in the filtrate 0.0008  $\text{Fe}_2\text{O}_3$  was found, about  $\frac{1}{57}$  the amount of gold. Schild\* states that ferric chloride attacks gold with formation of ferrous and auric chlorides. Napier† and Comey‡ state that ferric chloride dissolves gold, and Comey states that it is dissolved by hydrochloric acid containing ferric chloride.

In view of the fact that ferrous salts precipitate gold from solution very perfectly, it seems remarkable that the reaction given by Schild could take place to such an extent as to dissolve a weighable amount of gold, and in any event it would not account for the solution of fifty parts of gold by one of iron. In the experiments cited the portion of the sealed tubes not occupied by liquid was full of air, and on measuring its volume it was found that sufficient oxygen was present in it to have reacted with the hydrochloric acid and gold to produce water and gold chloride in such quantities as were found in solution, providing that the small amount of ferric chloride was assumed to act as a carrier of chlorine from the hydrochloric acid to the gold. In order to ascertain definitely that it was the iron and not some other undiscovered impurity which had caused the gold to dissolve, a quantity of gold was obtained which had been purified at the New York Assay Office six times by solution, precipitation and fusion. Some of this gold was dissolved in aqua regia, precipitated with oxalic acid and washed for a long time by decantation with distilled water. 0.500 gram of this precipitated gold was placed in a tube with  $10^{\circ}$  hydrochloric acid and 0.0002 gram ferric chloride and the tube sealed without removing the air. Another tube was prepared containing the same

\* Berg. u. Hüttenm. Ztg., xlvii, 251. † Phil. Mag., 1844, iii, xxiv, 370.

‡ Dict. Sol., 172.

amount of gold and acid but twelve times as much ferric chloride, and this tube was boiled for several minutes before sealing and sealed while still boiling in order to remove the air. After heating the tubes the liquid in the first was found to contain 0.0109 gold in solution, while in the liquid in the second tube a slight test for gold could be obtained only with difficulty, and it seemed likely that this small amount of gold might have been dissolved before the tube was boiled and after the materials had been added. Another small tube was prepared containing about a gram of ferric chloride dissolved in concentrated hydrochloric acid and the tube boiled to expel air and sealed while boiling. This tube was placed in a larger tube containing concentrated hydrochloric acid and 0.500 gram gold and the liquid in the larger tube also boiled for some minutes and sealed boiling. The smaller tube was then broken by shaking, allowing the iron to mix with the acid and come in contact with the gold without access of air. This tube was then heated as the others had been and the liquid tested for dissolved gold. Not a trace was to be found.

It thus appears that hydrochloric acid in presence of air is without action on metallic gold, that ferric chloride is without action on gold unless oxygen is present, but that ferric chloride acts as a very efficient carrier of chlorine in the presence of hydrochloric acid and oxygen. This fact helps to account for the solubility of gold in mine waters and in other waters containing iron, acid, and common salt.

Metallurgical Laboratory, Columbia University, N. Y.



ART. XLV.—*The Geology of Block Island*; by O. C. MARSH.

A RECENT visit to Block Island gave me an opportunity to examine its geological structure, and this proved much more interesting than the published accounts had led me to expect. I had previously seen this island only from a distance, yet I supposed from what I had read that it contained none of the older rocks in place, but was a remnant of the great terminal moraine that, in the glacial period, was pushed over from the main land of southern New England, and left its debris as Long Island and the other islands to the eastward.\* That Block Island was once connected with Long Island is suggested by a glance at a map of the New England coast, and that the same great moraine extended over both is equally evident from facts well known. An examination of Block Island itself, however, soon proved to me that these glacial deposits were merely a superficial covering, while the main body of the island was formed of much older beds, the exact age of which offers a most interesting problem.

These lower strata consist mainly of massive beds of clay, more or less arenaceous, and all considerably disturbed. The general inclination is to the northeast, as is well shown in the fine sections exposed on the coast, especially in the bluffs on the east and south of the island, which are rapidly wearing away from the assaults of Atlantic waves. Some of these clays are white in color, as seen in the cliffs at Clay Head, on the northeast shore of the island. Some bright-red clays also occur near the water's edge at low tide, at the foot of the same bluff, but the most of these deposits are gray or brown in color. At a few points, where carbonaceous matters have discolored them, they are nearly or quite black, and in such places, specimens of fossil wood and other plant remains are comparatively abundant. One locality of this character may be seen in a bluff on the southeast shore, a short distance west of the Ocean View hotel. Another marked character of these clay cliffs is the deposits of iron they contain. This ore is mainly limonite, usually in thin seams, and its decomposition has stained the layers in many places a rusty color, which frequently serves to indicate the dip of the strata. Iron pyrites occurs in the dark clays with the plant remains.

These massive beds of clay, with their characteristic features, are well shown in all the high cliffs of the coast that are being rapidly eroded by the ocean storms. The famous Mohegan

\* Seventh Annual Report U. S. Geol. Survey, p. 304, 1888; and Bulletin U. S. Geol. Survey, No. 53, p. 11, 1889.

Bluffs, on the southeast shore of the island, afford a fine example of this, as here the clays show a vertical thickness of about a hundred and fifty feet. Judging by the inclination of the beds, which are highly inclined, a great thickness of strata is here represented. This fact, together with the disturbance they have undergone, is an important element in the problem of their age, and indicates for them a much greater antiquity than would otherwise be supposed from the nature of the deposits themselves.

These foundation clays of Block Island were evidently much eroded before the glacial drift was spread over them. They still constitute the bulk of the island, and their depressions form an impervious stratum for the bottom of the numerous ponds for which the island is renowned. These clays all appear to be fresh-water deposits, and should certainly contain vertebrate fossils. I found none in the limited time at my command, but more careful exploration would undoubtedly bring them to light, and thus determine the geological age of these interesting beds. In the mean time, a comparison of various deposits at some other points on the coast may, perhaps, suggest a solution of this problem.

In exploring the Tertiary and Cretaceous strata of the Atlantic coast south of New York, I have had much experience, but know of nothing in these two formations there exposed that offers a parallel to the deposits now under discussion. The still older Potomac beds, however, have many similar features, and to this horizon I should be inclined, on present evidence, to refer the greater portion, at least, of the Block Island clays. From the Potomac formation in Maryland, I have secured a large collection of fossil vertebrates that indicate a period corresponding nearly to the Wealden of England, which is now regarded by the best authorities as late Jurassic, and to this age the vertebrate fossils of the Potomac may likewise be assigned.\* The special horizon in which these vertebrates are most abundant in Maryland may be called the *Pleurocoelus* beds, from a genus of Dinosaurs found there, especially in the iron-ore clays, which are similar in physical characters to some on Block Island.

The Raritan clays of New Jersey, I regard as belonging to the same series as the Potomac beds, since they hold the same relative position stratigraphically, while the only vertebrate fossils thus far reported from them (remains of a Dinosaur and a Plesiosaur, both preserved in the Yale Museum) also tend, in part, to confirm this view. The latter is probably from a higher horizon.

\* This Journal, vol. xxxv, p. 90, 1888. See, also, Sixteenth Annual Report U. S. Geol. Survey, Part I, p. 183, 1896.

The well known clay deposits of Long Island I have not carefully examined in place. There is much in the published descriptions of them, however, to indicate that they may represent some of the same Jurassic beds. Near the eastern end of the island, there are beds of clay closely resembling some on Block Island.

The clay bluffs at Gay Head, on Martha's Vineyard, have many characteristics of the same series, but the presence of Cetacean remains in one portion of them indicates that this is Tertiary. There are, however, some reasons for supposing that the most of the clays are much older, and I believe they contain representatives of the same great Jurassic formation. Some of the vertebrate remains from Gay Head, described as Reptilian (*Graphiodon*), I found on examination to be Cetacean, and it is possible that others, now regarded as Cetacean, may prove to be Dinosaurian, as was the case with some Potomac fossils.

The massive clay beds of Block Island were derived from the decomposition of the granitic rocks to the north, and were deposited in quiet waters. The iron ore now in them came also from the northern crystalline rocks mainly as magnetite, which may still be seen in the sands of all the beaches of the island, and on one of them this mineral sand was for a while used in making metallic iron.

There appear to be no crystalline rocks in place on the island, although some of the large imbedded boulders might readily suggest such outcrops. The glacial drift covers most of the surface, and the hills and shores are strewn with boulders of crystalline rocks,—granite, gneiss, quartz, etc., that came over the ice from the main land on the north. Large masses of both the porphyritic and the garnet-bearing gneiss, waifs from the Rhode Island shore, may be easily recognized, and in the beach sand resulting from the attrition of the latter, the separate garnets may be found.

On some of the glacial hills near the shore, or around the Great Pond, shell heaps of considerable antiquity may be observed, but so far as I could ascertain, none of them have been explored. One may be seen on the south side of the road recently cut through a low hill, near the new steamboat landing on Great Pond. The deposits are several feet in thickness, indicating a long occupancy of the place by some of the early inhabitants of the island. The short examination I was able to give this "kitchen midden" disclosed many marine shells, mainly species now living in the adjacent waters, the most abundant of which were those of oysters, clams, and scollops. Mingled with these were a few bones of fishes, birds, and small mammals.



The presence of such great masses of stratified clay, evidently of high antiquity, on this diminutive island facing the Atlantic, opens up many questions of interest beyond the mere geological age of the deposits. These beds of clay must be the remnants of a great formation, which extended out far beyond the present coast line, and being of fresh-water origin and laid down in quiet waters, they prove the former existence of an extensive barrier along the continental border between them and the Atlantic depths beyond.

It has long been a reproach to American geologists that they could find no true Jurassic on the Atlantic coast, although the next formations above and below are well developed at many points. May not the missing strata be represented in the characteristic series of Block Island clays? The evidence as it stands to-day points to this conclusion.

New Haven, Conn., September 5, 1896.

#### *Postscript.*

Since the above was in print, I have visited Long Island and Martha's Vineyard to ascertain if the Block Island clays are represented there, as they should be if my conclusions are correct. On Martha's Vineyard, I found that the great series of variegated clays forming Gay Head, and generally regarded as Tertiary, are certainly Mesozoic, and all apparently Jurassic. They have the same general features as the Block Island clays, but are more highly colored, and have been more disturbed. They, also, suffered much from denudation before the Glacial period.

Prior to that period, however, they were covered by a series of marine Miocene deposits, remnants of which still rest unconformably upon them. The vertebrate fossils reported from Gay Head were apparently all from this horizon, which also contains many mollusks.

The cliffs of Gay Head are rapidly washing into the sea, the base being first undermined by storms, causing very extensive landslides which have led to much confusion in regard to the natural position and mutual relations of the various strata.

On Long Island, I visited a number of localities, including Montauk Point, where there are clay beds similar to those on Block Island, although possibly of somewhat later date. Other preglacial freshwater clays at various points on the north shore appear to be of the same age as those at Gay Head. I hope soon to discuss this subject more fully elsewhere.

New Haven, Conn., September 21, 1896.

## SCIENTIFIC INTELLIGENCE.

## I. CHEMISTRY AND PHYSICS.

1. *An Empirical Relation between Melting-point and Critical Temperature.*—F. W. CLARKE calls attention to a remarkable relation which appears to exist between the two constants under consideration. The data are very meager, but the author has been able to examine the ratio in the case of about thirty substances.

In nine cases the absolute melting point is nearly, if not exactly one-half the absolute critical temperature, that is, *the thermometric lengths for the solid and liquid states are equal*. The following table gives the data in these cases, where  $t$  is the melting-point,  $T$  the critical temperature, and the ratio that of the absolute temperatures,  $\frac{T + 273^\circ}{t + 273^\circ}$ .

|                         | $t$<br>degrees | $T$<br>degrees. | Ratio. |
|-------------------------|----------------|-----------------|--------|
| Nitrogen .....          | -214.0         | -146.0          | 2.18   |
| Carbonic oxide .....    | -207.0         | -139.5          | 2.02   |
| Argon .....             | -190.0         | -121.0          | 1.83   |
| Methane .....           | -186.0         | -82.0           | 2.19   |
| Hydrochloric acid ..... | -112.5         | + 52.0          | 2.02   |
| Hydrogen sulphide ..... | - 86.0         | +100.0          | 2.00   |
| Ammonia .....           | - 75.0         | +130.0          | 2.03   |
| Benzene .....           | + 3.0          | +288.5          | 2.04   |
| Acetic acid .....       | + 17.5         | +322.0          | 2.05   |

This simple relation, however, is not general, but there are other marked regularities among related compounds. The following gaseous compounds of nitrogen give closely agreeing results:

|                | $t$<br>degrees. | $T$<br>degrees. | Ratio. |
|----------------|-----------------|-----------------|--------|
| $C_2N_2$ ..... | - 34.5          | +124.0          | 1.67   |
| $N_2O_4$ ..... | - 10.0          | +171.0          | 1.64   |
| $NO$ .....     | -167.8          | - 93.5          | 1.70   |
| $N_2O$ .....   | - 99.0          | + 35.5          | 1.77   |

Five aromatic bodies give:

|                        | $t$<br>degrees. | $T$<br>degrees. | Ratio. |
|------------------------|-----------------|-----------------|--------|
| <i>o</i> -Xylene ..... | -45.0           | +358.0          | 2.77   |
| <i>m</i> -Xylene ..... | -53.0           | +346.0          | 2.81   |
| $C_6H_5Cl$ .....       | -40.0           | +361.0          | 2.78   |
| $C_6H_5Br$ .....       | -30.5           | +397.0          | 2.75   |
| $C_6H_5I$ .....        | -28.5           | +448.0          | 2.94   |

For most of the other substances the ratios range between 2.2 and 3.0, thus:

|                        |      |                                     |      |
|------------------------|------|-------------------------------------|------|
| Br <sub>2</sub> .....  | 2.17 | H <sub>2</sub> O.....               | 2.34 |
| Cl <sub>2</sub> .....  | 2.44 | SnCl <sub>4</sub> .....             | 2.47 |
| SO <sub>2</sub> .....  | 2.22 | CHCl <sub>3</sub> .....             | 2.62 |
| CCl <sub>4</sub> ..... | 2.25 | C <sub>2</sub> H <sub>4</sub> ..... | 2.75 |

The value for carbon dioxide is only 1.41, while a few bodies give ratios higher than three, ether 3.06, CS<sub>2</sub> 3.36, PCl<sub>3</sub> 3.47, alcohol 3.59.

The author offers no explanation of these ratios, but believes that they are not meaningless.—*Am. Chem. Journal*, xviii, 618.

H. L. W.

2. *The Quantitative Separation of Chlorine, Bromine and Iodine*.—BENNETT and PLACEWAY have applied the qualitative method, described by Prof. Edward Hart a number of years ago, to the quantitative separation of the halogens with satisfactory results. The method recommended is briefly as follows: To a solution of the alkali salts in a distilling-flask, a solution of 10% of ammonium ferric alum is added with water enough to make a total volume of about 200<sup>cc</sup>, and the mixture is distilled for about 25 minutes. The iodine is absorbed in a receiver with a solution of potassium iodide and titrated with sodium thiosulphate. To determine bromine, 35<sup>cc</sup> of a saturated solution of potassium permanganate are added to the residue in the distilling-flask, water is added to make the volume 200<sup>cc</sup> as at first, and a distillation is made exactly as in the previous case. Chlorine can be determined in an aliquot part of the final residue in the distilling-flask either by a volumetric or a gravimetric method.—*Jour. Am. Chem. Soc.*, xviii, 688.

H. L. W.

3. *The homogeneity of Argon and of Helium*.—RAMSAY and COLLIE have studied this interesting question by submitting the two gases to systematic diffusion, dividing each gas into two parts by a method analogous to fractional distillation. The gases were caused to traverse a duct of porous pipe-clay, submitted on one of its surfaces to the action of a vacuum. The authors satisfied themselves that the separation of hydrogen and helium and that of oxygen and carbonic acid could be effected in this way, and that, by measuring the descent of a column of mercury connected with the apparatus, it is possible to arrive at a good determination of the molecular weight of various gases.

When argon was submitted to this fractionation, the two extreme portions had densities of 19.93 and 20.01. The separation, if any, in this case was very slight.

With helium the results were different. A more diffusible part with a density of 1.874 was obtained, while, at the other end, the gas had a density of 2.133. A great number of further fractionations did not change these densities. The two fractions, however, showed absolutely identical spectra. Considering what happens when a mixture of two gases is diffused, as, for example,



when a mixture of an excess of oxygen with hydrogen is sufficiently fractionated, pure oxygen is obtained on the one hand, while on the other hand a mixture of one part of hydrogen with four parts of oxygen diffuses unchanged, the authors have calculated that if helium consists of a mixture, it is composed either of two gases of the densities 2.366 and 1.874 or of two with the densities 2.133 and 1.580.

The authors finally mention what they consider a possible explanation of this behavior of helium, in that the heavy molecules may have been separated from lighter molecules of the *same gas*. They state that the idea that all the molecules of a gas are homogeneous has never been submitted to the test of experiment, and they believe that this question deserves further study.—*Comptes Rendus*, cxxiii, 214. H. L. W.

4. *Argon and Helium from a Natural Spring*.—CH. MOUREU has examined the gas from a spring at Maizières (Côte-d'Or), and has found it to contain a small quantity of oxygen, about 2 per cent, the remainder showing the negative characters of nitrogen. After the absorption of nitrogen by metallic lithium, a remarkably large residue remained, amounting to between  $\frac{1}{15}$  and  $\frac{1}{10}$  of the total volume, giving the characteristic spectrum lines of argon and helium.—*Bull. Soc. Chim.*, xv, 626. H. L. W.

5. *The liquefaction of helium*.—OLSZEWSKI, working upon a sample of helium gas obtained by Ramsay from the mineral cleveite, has found that it remains permanent even under the most extreme conditions as to temperature and pressure available. In one series of experiments the helium, confined under a pressure of 125 atmospheres, was cooled to the temperature of oxygen, boiling first under atmospheric pressure ( $-182^{\circ}5$ ) and then under a pressure of  $10^{\text{mm}}$  of mercury ( $-210^{\circ}$ ). In neither case did it condense, nor was there any indication of liquefaction even when the gas was expanded till the pressure fell to one atmosphere. In the second series of experiments liquid air boiling at  $10^{\text{mm}}$  of mercury (about  $-220^{\circ}$ ) was employed, the helium being under a pressure of 140 atmospheres; but here also the results were negative. Theoretical calculations, based upon the formula of Laplace and Poisson for change of temperature under adiabatic expansion, led to the conclusion that the boiling point of helium lies below  $-264^{\circ}$ , or at least  $20^{\circ}$  lower than the values obtained by Olszewski for hydrogen. The higher density of helium, however, would lead one to expect that the boiling point would also be above that of hydrogen.—*Nature*, liv, 377.

## II. GEOLOGY AND MINERALOGY.

1. *Glacial deposits, preglacial valleys, and interglacial lake-formation in Subalpine Switzerland*.—Dr. C. S. DU RICHE PRELLER read an interesting paper with the above title before the Geological Society of London in May last. The conclusions he reached after a careful examination of the evidence, particu-

larly in the Zurich valley and its neighborhood, appear to be well established. As they differ from the usual interpretation of the phenomena, their reproduction here will call the attention of our readers to their importance.

"It will be observed that the conclusions at which I have arrived in this paper differ in some respects widely from the views recently enunciated by several Swiss geologists. More especially does this difference relate to the question whether the principal Subalpine valleys were excavated before or after the first or Upper Pliocene glaciation.

Apart from the evidence I have adduced, my conclusion that the first glaciation found the principal Subalpine valleys already eroded derives substantial support from the very history of the Tertiary epoch. In Eocene times the Alps had already emerged from the surrounding sea, though as yet only as a group of low islands. The Miocene period witnessed the principal thrusting and folding of the Jura and the Alps: and the products of increased denudation—namely, sand and clay, afterwards hardened to Molasse, and fluvial detritus subsequently cemented to compact conglomerate—were deposited between the two ranges in two freshwater and one intermediate marine series, the latter being formed in an arm of the sea which, towards the end of the Miocene period, still reached from the Mayence basin to the foot of the Alps. The process of folding continuing, the Subalpine Molasse and the enormous banks of conglomerate, too, were raised, notably near the Alps; the sea receded; the lakes formed in the shallow depressions of the Molasse plateau dried up, and, consequent upon the increased steepness of the Alpine slopes, denudation and erosion set in on a greatly enhanced scale; rapids and ravines formed; the great Alpine rivers effected in the Miocene Nagelfluh walls those breaches which later on afforded easy and convenient passages to glaciers; and broad valleys were eroded in the soft Molasse strata of the Swiss lowlands, the general direction of discharge being towards the natural collecting-channel along the foot of the Jura, and thence to the Rhine. Thus, the Lower and Middle Pliocene period in Subalpine Switzerland did not witness the deposition of any new rock-formations, but was an unbroken period of erosion and denudation on a prodigious scale. The long duration of this post-Miocene and pre-Glacial period appears the more obvious when we reflect that it was contemporaneous with the formation of the extensive marine beds of the Subapennine hills and of Sicily.

It is a singular fact that the geological epoch which immediately preceded the appearance of man is perhaps the most difficult to unravel. But unless we assume that in this post-Miocene and pre-Glacial period, which Sir Charles Lyell regarded as of incalculable duration, the work of Nature stood still, we are driven to the conclusion that, at the advent of the first Ice-period in Upper Pliocene times, the principal Subalpine valleys were already excavated approximately to their present depth, and that

ever since then the action of the great Alpine and Subalpine rivers has been, as it still is in our own day, mainly directed to regaining the old valley-floors by removing those enormous accumulations of glacial and glacio-fluviatile material which are respectively the direct and indirect products of three successive and general glaciations.—*Q. J. G. Soc.*, lii.

2. *U. S. Geological Survey*.—The completed volumes of Parts II, III and IV of the Sixteenth Annual Report have been issued, and notice has already appeared in our pages of the director's official report and several separate papers of Part I already published.\*

Part II contains papers of an economic character. Among them are the report on the "Geology and mining industries of the Cripple Creek district, Colorado," by Whitman Cross and R. A. F. Penrose Jr. (pp. 1-210), and Mr. F. N. Newell's report on "The Public Lands and their water supply" (pp. 457-588).

Parts III and IV contain the annual report (for 1894) on the Mineral Resources of the United States, which has heretofore been published as a separate report, now appearing as two large volumes, Part III on metallic products and IV on non-metallic products. These volumes were prepared, as the earlier ones of the same series, by David T. Day, geologist in charge, with the assistance of specialists.

3. *Bibliography and Index of North American Geology, Paleontology, Petrology, and Mineralogy for 1892 and 1893*; by F. B. WEEKS. Bulletin No. 130, U. S. Geological Survey.—This Bulletin is a continuation of the annual publication heretofore known as the "Record of North American Geology" (Bulletins Nos. 44, 75, 91, 99). The extended scope of the work necessitated a change in its arrangement. It is divided into two parts; a bibliography and a subject index. The bibliography is arranged alphabetically by author's names. The index comprises geographic, geologic, mineralogic, paleontologic, and petrologic subdivisions, arranged alphabetically; and lists of economic products, minerals, rocks, and fossils described in the various papers listed in the bibliography are given. A similar bibliography and index for the year 1894, and another for the year 1895 (Bulletins Nos. 135 and 146, respectively) are in press and will be delivered soon.

4. *Iowa Geological Survey*.—The Annual Report for 1895, with accompanying papers by State Geologist Samuel Calvin and Assistant H. Foster Bain, has appeared with the usual amount of new contributions in the elaboration of the geology of this state. The special reports in this volume cover the counties of Jones, Washington, Boone, Woodbury, Warren and Appanoose.

5. *Elements of Geology, a text-book for colleges and the general reader*, by JOSEPH LECONTE, 4th edition, revised and enlarged, with new plates and illustrations, pp. 670. (D. Appleton & Co.) 1896.—This excellent text-book of geology, improved by the revision, the addition of new matter and many new figures,

\* This Journal, vol. cli, pp. 142-146.



comes to us in a new edition with all the merits of the old well-attested by a wide usage in the colleges of the land. As the author set forth to do in the preface to the first edition, he has succeeded in doing: viz. the making of a work "which shall be both interesting and profitable to the intelligent general reader, and at the same time a suitable text-book for the higher classes of our colleges."

Some additions as well as changes in the arrangement have been made, the most important of which are "a fuller discussion of the difficult subject of *earthquakes*, in the light of the recent investigations of Milne, Dutton, Seebach and Schmidt; a brief account of the origin of *varieties of igneous rocks by differentiation of rock-magmas*, made necessary by the writings of Iddings and others; a greater emphasis on the *Cambrian* as a subdivision of the Palæozoic; the latest results of Walcott, Matthew, and Beecher on the *structure and affinities of Trilobites*: the latest results of Marsh, Cope, Osborn, Scott, and Wortman on the *structure and affinities of Mesozoic reptiles and Mesozoic and Tertiary mammals*; some clearer statement on the *subject of the causes of the glacial climate*; and a brief discussion of the *causes of geological climates in general*."

6. *On the amount of gold and silver in sea-water*.—Prof. A. Liversidge has carried on a series of experiments made with the object of determining the amount of gold in the sea-water off the coast of New South Wales. The method of Sonstadt (Chem. News, 1872, pp. 159, 160 and March 11, 1892) was employed. After detailing the separate experiments and remarking that the amount of gold found must necessarily be less than the total amount present in the water, the author concludes that all the "evidence is in favor of gold being present in sea-water off the New South Wales coast in the proportion of about 5 to 1 grain per ton, or in round numbers from 130 to 260 tons of gold per cubic mile. This of course means an enormous amount for the whole of the ocean, the cubic contents of which used to be put down at 400,000,000 cubic miles, and if the gold be uniformly present at the rate of 1 grain per ton the total amount would be over 100,000,000,000 tons of gold; a later estimate is 308,710,679 cubic miles; this even would mean over 75,000,000,000 tons of gold. But at the present day it would probably not pay to extract the gold by itself, although it might as a bye-product in the manufacture of salt, bromine, etc. The enormous amount of gold in the sea is, however, probably very small in comparison with the amount scattered through sedimentary and crystallized rocks, i. e., apart from gold in veins and other deposits." He adds further that all the sea-waters gave some silver, usually from one to two grains per ton, but the scorification and cupellation process were lacking in the necessary precision for the exact determination of silver in such minute quantities as it exists in sea-water.

A subsequent article discusses the supposed removal of silver and gold from sea-water by Muntz metal sheathing. The results

of the experiments do not altogether agree with previously published views. The author finds that "the silver has not accumulated, but on the contrary decreased; the scale, however, contains a larger amount of gold. The increase of gold in the scale may be due to the deposition of gold from the sea-water on to the surface of the metal, or it may be due to the comparative non-solubility of gold in sea-water; the muntz metal having been corroded and dissolved away, together with much of the silver, leaving the gold behind." He believes that it is "probably due to both causes, i. e., partly to deposition and partly to accumulation, for the superficial parts of certain of the experimental plates obtained by scraping them, show an increase in the amount of gold and a decrease in the amount of silver; the increase in the gold cannot in these cases well be due to mere accumulation, since the plates do not appear to have lost sufficient weight to materially increase the proportion of the residual gold."

7. *Brief notices of some recently described minerals.*—**RATHITE**, named by Baumhauer after Gerhard vom Rath, is a new mineral from the dolomite of the Binnenthal, a region to which the honored German mineralogist devoted much study. It occurs in slender needle-like crystals belonging to the orthorhombic system; these have a prismatic development parallel to the macro-diagonal axis with fine striations and approximate to dufrenoyite in angle; they are in part twins. It resembles dufrenoyite in color and luster. An analysis by A. Bömer gave:

| S     | As    | Sb   | Pb    | Fe           |
|-------|-------|------|-------|--------------|
| 23.72 | 17.24 | 4.53 | 52.98 | 0.56 = 99.03 |

The exact formula remains in doubt.—*Zeitschr. Kryst.*, xxvi, 593, 1896.

**SALVADORITE** is a new copper-iron vitriol from the Salvador mine, Quatena, Chili. It occurs as a crystalline aggregate of a bluish green color. Analyses of two kinds gave:

|            | SO <sub>3</sub> | CuO   | FeO  | H <sub>2</sub> O |
|------------|-----------------|-------|------|------------------|
| Green..... | 27.87           | 18.77 | 8.49 | 44.65 = 99.78    |
| Blue.....  | 28.16           | 17.57 | 9.59 | 44.31 = 99.63    |

For these the formula,  $\text{FeCu}_2(\text{SO}_4)_3 + 21\text{H}_2\text{O}$  is calculated. This brings it near pisanite, from which, however, it differs in optical characters. Described by W. Herz in *Zeitschr. Kryst.*, xxvi, 16, 1896.

**CASWELLITE**, named after John H. Caswell of New York, is an altered biotite from Franklin Furnace, New Jersey. It has a copper-red or flesh color, resembling a light-colored clintonite; hardness 2.5–3; specific gravity 3.54. It retains the cleavage but has lost the elasticity of the original mineral. It is associated with massive yellow garnet and rhodonite. An analysis gave:

|               | SO <sub>2</sub> | Fe <sub>2</sub> O <sub>3</sub> | Al <sub>2</sub> O <sub>3</sub> | Mn <sub>2</sub> O <sub>3</sub> | CaO   | MgO  | ign.          |
|---------------|-----------------|--------------------------------|--------------------------------|--------------------------------|-------|------|---------------|
| $\frac{2}{3}$ | 38.74           | 6.85                           | 6.58                           | 15.95                          | 22.30 | 5.52 | 4.64 = 100.58 |

Described by A. H. Chester in the *Ann. Rep. State Geologist of New Jersey* for 1895.

RHODOPHOSPHITE, TETRAGOPHOSPHITE are two partially described minerals from Horrsjöberg in Wermland, Sweden, named by Igelström. Rhodophosphite varies in color from white to red; it occurs in masses, associated with lazulite, cyanite, etc. The analysis shows a small amount of  $\text{SO}_3$ , but the large loss makes any conclusion as to the composition uncertain.

| $\text{P}_2\text{O}_5$ | $\text{SO}_3$ | FeO, MnO | CaO   | Cl   | F              |
|------------------------|---------------|----------|-------|------|----------------|
| 36.42                  | 1.31          | 8.80     | 45.17 | 2.92 | undet. = 97.93 |

Tetragophosphite is a mineral of a blue color resembling lazulite; it occurs in four-sided tabular crystals. One of two analyses gave:

| $\text{P}_2\text{O}_5$ | $\text{Al}_2\text{O}_3$ | FeO, MnO | CaO, MgO | $\text{H}_2\text{O}$ |
|------------------------|-------------------------|----------|----------|----------------------|
| 36.92                  | 40.00                   | 9.51     | 7.50     | 5.96 = 100           |

—*Zeitschr. Kryst.*, xxv, 444, 1895.

BLIABERGITE and RANSÄTITE are two other names given by the above author to minerals from the Bliaberg in the Ransät parish, Wermland, Sweden; they occur associated with damourite. Bliabergite occurs in small hexagonal crystals of a reddish color; hardness 4.5. An analysis gave:

| $\text{SiO}_2$ | $\text{Al}_2\text{O}_3$ | FeO   | MnO  | MgO, CaO | $\text{H}_2\text{O}$ |
|----------------|-------------------------|-------|------|----------|----------------------|
| 39.13          | 27.60                   | 26.74 | 4.45 | 0.43     | 3.26 = 101.61        |

*Ransätite* occurs in hard red spherules in damourite. Analysis gave:

| $\text{SiO}_2$ | $\text{Al}_2\text{O}_3$ | $\text{Fe}_2\text{O}_3$ | MnO   | CaO  | MgO          |
|----------------|-------------------------|-------------------------|-------|------|--------------|
| 43.47          | 14.50                   | 17.72                   | 14.97 | 5.63 | 2.57 = 98.86 |

—*Geol. För. Förhandl.*, xviii, 41, 1896.

8. *A mineralogical Lexicon of Franklin, Hampshire and Hampden Counties, Massachusetts*, by BEN K. EMERSON. Bulletin of the U. S. Geological Survey, No. 126. 180 pp. Washington, 1895.—This bulletin gives a full list of the minerals occurring in the three counties named, with historical notes, brief descriptions of species and occasional descriptions of crystals, new analyses, etc. The account of the remarkable crystals of stolzite and wulfenite from Loudville is especially to be noted.

9. *Recent works on Crystallography*.—The following works in this department have been received recently:

“Grundriss der Krystallographie für Studirende und zum Selbstunterricht,” von Dr. GOTTLÖB LINCK. 252 pages. Jena, 1896. (Gustav Fischer.)—This is an elementary work, embracing not only crystallography proper but also physical mineralogy. It has been prepared for beginners and those who may not have the advantages of a teacher, and hence is limited to the more elementary parts of the subject. These are well presented and fully illustrated.

“Lecture Notes on Crystallography,” by HORACE B. PATTON.—This is a brief work (34 pp.) intended to be used in connection with lectures and practical exercises. It is clear and simple in



style and systematic in method and is likely to prove useful to students.

"Calcolo cristallografico:" Appendice al Trattato di Mineralogia, volume I, di Ruggero Panebianco, 48 pp. with 3 plates.—This appendix gives methods of calculation, formulas employed and practical illustrations of their use.

"Éléments de Cristallographie," 2me partie, Description de systèmes cristallines, par G. DEWALQUE. 103 pp. with 174 figures in the text. Liège.—A concise description of the different crystalline systems with the types of forms belonging to each.

### III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *American Association for the Advancement of Science.*—The forty-fifth meeting of the American Association was held at Buffalo, N. Y., from August 24 to 29. The President of the meeting was Professor Edward D. Cope of Philadelphia. It is interesting to note that the Association has met three times previously in the same city, the last time in 1886. The present gathering was small, in fact one of the smallest in recent years, but in some respects the meeting was regarded as one of more than usual interest. One of the notable events was the delivering of the address by the retiring President, Prof. E. W. Morley of Cleveland, upon the subject "A completed chapter in the history of the atomic theory." Addresses were also delivered by the Vice-Presidents of the several sections. A commemorative meeting was held on Wednesday, August 26, in recognition of the geological work of Professor James Hall, extending over a period of sixty years. Special business transacted included a resolution favoring the introduction of the metric system, another opposing legislation against vivisection; a report from the committee on electrical standards, etc. The future policy of the Association, particularly as regards its relations to affiliated societies, was considered by the Council, but no conclusion was announced.

The city of Detroit was selected for the next meeting in 1897, and Dr. Wolcott Gibbs of Newport was chosen President. The Vice-Presidents elected to the several sections are as follows: *Section A*, W. W. Beman, of Ann Arbor, Mich.; *Section B*, Carl Barus, of Providence, R. I.; *Section C*, W. P. Mason, of Troy, N. Y.; *Section D*, John Galbraith, of Toronto, Canada; *Section E*, I. C. White, of Morgantown, W. Va.; *Section F*, G. Brown Goode, of Washington, D. C.;\* *Section G*, George F. Atkinson, of Ithaca, N. Y.; *Section H*, W. J. McGee, of Washington, D. C.; *Section I*, Richard T. Colburn, of Elizabeth, N. J.

The following are the titles of papers accepted for reading:

#### SECTION A. *Mathematics and Astronomy.*

JAMES McMAHON: A proposed fundamental integral-transcendent.

EDWIN B. FROST: On the level of sun-spots.

JAMES B. SHAW: Sedonians.

\* Dr. Goode died on the 6th of September.

- J. R. EASTMAN: Determination of weights of observation.  
 L. A. BAUER: On the distribution and the secular variation of terrestrial magnetism. No. IV. On the component fields of the earth's magnetism.  
 A. MACFARLANE: On the composition of simultaneous and successive vectors.

SECTION B. *Physics.*

- F. E. MILLIS: An experimental study of the charging and discharging of condensers.  
 W. LECONTE STEVENS: Notes on certain physical difficulties in the construction of modern large guns.  
 ERNEST MERRITT: On the photographic trace of the curves described by the gyroscopic pendulum. On the distribution of high frequency alternating currents throughout the cross-section of a wire.  
 E. R. VON NARDROFF: On the compactness of a beam of light.  
 W. S. FRANKLIN: Some points in the mechanical conception of the electromagnetic field.  
 BROWN AYRES: Mechanical models of the electric circuit.  
 HENRY T. EDDY: Graphical treatment of alternating currents in branching circuits.  
 FREDERICK BEDELL and JAMES E. BOYD: Note on the effect of odd harmonics upon the virtual values of periodical varying quantities.  
 ALEXANDER MACFARLANE: On the rule for the dynamo and motor.  
 W. A. ROGERS: Description and exhibition of a convenient form of the "Interferential Comparer," and of an interferential caliper attachment for use in physical laboratories. Description and exhibition of a bench comparator for general use in physical laboratories. Experimental determination of the relative amounts of work done in changing the lengths of two metal bars under the same thermal conditions, by an envelope of heated air, and by pure radiations in a vacuum. An experimental method of finding the value of a unit of force in any system whatever.  
 EDWARD B. ROSA: A new alternating-current curve-tracer.  
 B. E. MOORE: Visible electric waves.  
 A. D. COLE: Electric waves in long parallel wires.  
 EDWARD L. NICHOLS and JOHN ANSON CLARK: The influence of a static charge of electricity on the surface tension of water.  
 W. S. FRANKLIN and L. B. SPINNEY: Determination of the specific heats of nitrogen by adiabatic expansion.  
 L. B. SPINNEY: The analysis of vowel-sounds, by means of the sympathetic vibrations of a rigid body.  
 C. P. HART: Polar and interpolar effects of the galvanic current on living animal tissues.  
 H. J. HOTCHKISS: Description and exhibition of a portable apparatus for recording curves of alternating currents and electro-motive force.

SECTION C. *Chemistry.*

- T. H. NORTON: Points in teaching technical chemistry. On some new forms of gas generators.  
 G. C. CALDWELL: The aim of qualitative analysis.  
 H. P. TALBOTT: The aim and methods of the college course in qualitative analysis.  
 A. L. GREEN: The teaching of qualitative analysis.  
 F. P. VENABLE: The use of the periodic law in teaching general chemistry.  
 W. P. MASON: Chemistry at the Rensselaer Polytechnic Institute.  
 P. C. FREER: Laboratory instruction in organic chemistry.  
 A. A. NOYES: Laboratory instruction in organic chemistry. The teaching of physical chemistry.  
 ELLEN H. RICHARDS: Instruction in sanitary chemistry at the Mass. Institute of Technology.  
 J. L. HOWE and P. S. MERTINS: Notes on Reinsch's test for arsenic and antimony.  
 E. D. CAMPBELL: The limits of accuracy in analytical work.

ELLEN H. RICHARDS: Some points in the use of depths of color as a measure of chemical contents. The action of organic acids upon the mineral constituents of soils, or some compounds of iron with organic acids. Corrosion of metals by water. The meaning of the term "oxygen consumed" in the report of a water analysis.

ERWIN E. EWELL: A new form of laboratory condenser. A method of manipulation for the colorimetric determination of ammoniacal nitrous and nitric nitrogen in bacterial culture.

F. C. PHILLIPS: A new method for the determination of sulphur in white iron.

E. A. DE SCHWEINITZ: The necessity of animal experimentation in the study of bio-chemistry.

V. K. CHESTNUT: Andromedotoxin, the poisonous constituent of the Ericaceae and its relation to some food products.

LOUIS KAHLENBERG and R. H. TRUE: The toxic action of dissolved salts and their electrolytic dissociation.

W. P. MASON: Well water.

E. A. DE SCHWEINITZ: Value and use of formaldehyde as a disinfectant.

L. W. ANDREWS: Should the practice of embalming the dead be restricted by law?

E. G. SMITH: Observations on the sanitary nature of the Mississippi river water at different seasons.

H. W. WILEY: A modified form of the ebullioscope.

C. B. DUDLEY: Some applications of chemistry to railroads.

A. R. LEEDS: Recent developments in the purification and filtration of water.

C. PHILLIPS: Some properties and uses of natural gas. A new method for the determination of sulphur in white iron.

KARL LANGENBECK: The chemical problems of the pottery industry.

W. C. STUBBS: Sugar-making at the present day.

H. H. NICHOLSON: Some by-products of the sugar industry.

C. F. MABERY: Composition of American petroleum.

H. A. WEBER: Use of coal tar colors in foods.

E. W. HILGARD: Some points in the composition of California wines.

ERWIN E. EWELL: The alkaloids of *Anhelonium lewinii* (Mescal buttons).

L. L. VAN SLYKE: The work of the agricultural chemists of America.

S. M. BABCOCK and H. L. RUSSELL: Conditions affecting the normal viscosity of milk. On the restoration of the viscosity of Pasteurized milk and cream.

S. M. BABCOCK: A method of measuring the ripening of cheese.

#### SECTION D. *Mechanical Science and Engineering.*

WM. A. ROGERS: On the conversion of an ordinary planer into an apparatus for precise graduations.

J. H. KINEALY: The friction of the water in the pipes of a hot water heating system.

D. S. JACOBUS: Apparatus for exhibiting the distribution of moisture in a steam main. Values of heat of combustion of various gases per cubic foot for use in calculating the heating power from the analysis of a gas.

MALVERD A. HOWE: A new testing machine for beams and framed structures (capacity 50 tons).

THOMAS GRAY: On the yield point of steel.

W. S. ALDRICH: National endowment of engineering research.

R. H. RICHARDS: The cycle of the plunger-jig.

J. B. JOHNSON: Some results of the United States timber tests.

OLIN H. LANDRETH: Irrigation for the Eastern United States.

O. CHANUTE: Soaring flight.

M. E. COOLEY: The performance of small steam pumps.

#### SECTION E. *Geology and Geography.*

F. K. MIXER: The discovery of a new fish fauna, from the Devonian rocks of Western New York.

WARREN UPHAM: The Cuyahoga preglacial gorge in Cleveland, Ohio.

JAMES HALL: The operations of the Geological Survey of the State of New York.



- J. E. TODD: A revision of the moraines of Minnesota.  
 THOMAS H. MACBRIDE: Notes on certain fossil plants from the Carboniferous of Iowa.  
 I. C. WHITE: Origin of the high terrace deposits of the Monongahela River.  
 HORACE C. HOVEY: The making of Mammoth Cave. The colossal cavern.  
 CHARLES R. EASTMAN: Observations on the dorsal shields in the Dinichthyids.  
 GILBERT D. HARRIS: The Eocene stages of Georgia.  
 G. P. GRIMSLEY: The origin and age of the gypsum deposits of Kansas.  
 J. W. SPENCER: Geomorphic notes on Norway.  
 LEA MCL. LUQUER and HEINRICH RIES: The "Augen-Gneiss," pegmatite veins, and diorite dikes at Bedford, Westchester Co., N. Y.  
 W. J. MCGEE: Sheetflood erosion.  
 ALBERT P. BRIGHAM: Glacial flood deposits in the Chenango valley.  
 T. C. HOPKINS: Origin of conglomerates.  
 COLLIER COBB: Origin of topographic features in North Carolina.  
 ARTHUR HOLLOCK: The Cretaceous clay marl exposure at Cliffwood, N. J.  
 F. P. GULLIVER: Post-Cretaceous grade-plains in Southern New England.  
 E. H. WILLIAMS: Notes on Kansan drift in Pennsylvania.  
 H. B. BASHORE: Preliminary notes on the Columbian deposits of the Susquehanna.  
 G. K. GILBERT: The Algonquin River. The Whirlpool-Saint Davids channel. Profile of the bed of the Niagara in its gorge.  
 GEORGE W. HOLLEY: The Niagara Falls gorge.  
 WARREN UPHAM: Origin and age of the Laurentian Lakes and of Niagara Falls.  
 F. B. TAYLOR: Correlation of Warren beaches with moraines and outlets in southeastern Michigan. Notes on the glacial succession in eastern Michigan.  
 W. J. MCGEE: James Hall, founder of American stratigraphic geology.  
 JOHN M. CLARKE: James Hall and the survey of the fourth district.

SECTION F. *Zoology.*

- EDWARD D. COPE: The bone-fissure at Port Kennedy, Pennsylvania.  
 C. W. HARGITT: Notes upon Cordylophora.  
 SUSANNA P. GAGE: Modification of the brain during growth.  
 B. F. KINGSBURY: Structure and morphology of the oblongata of fishes. A note on the membranous roof of the prosencephal and diencephal of Ganoids.  
 WILLIAM ORR, JR.: Differentiation of work in zoology in secondary schools.  
 JAMES G. NEEDHAM: Field work and its utility.  
 AGNES M. CLAPOOLE: Appendages of an insect embryo.  
 C. W. HARGITT: Experiments upon regeneration and heteromorphosis.  
 E. D. COPE: The penial structures of the saurians.  
 ISABELLA M. GREEN: The peritoneal epithelium in amphibia.  
 GRANT S. HOPKINS: The heart of the lungless salamanders of Cayuga Lake.  
 GEO. V. REICHEL: Observation on the chameleon, *Anolis principalis*.  
 MANLY MILES: Energy in animal nutrition. Relative efficiency of animals as machines.  
 C. W. HARGITT: Some abnormal chick embryos.  
 EDWARD L. RICE: On a peculiar fusion of the gill-filaments in certain lamelli-branches  
 THEODORE GILL: The relationships of the North American faunæ.

SECTION G. *Botany.*

- W. W. ROWLEE: The development of the vascular elements in Indian corn. The stigma and pollen of *Arisæma*.  
 J. M. COULTER: Some remarks on chalazogamy. Embryo-sac structures.  
 L. M. UNDERWOOD: The habits of the rarer ferns of Alabama. Notes on the allies of the sessile *Trillium*.  
 FRANCIS RAMALEY: On the stem anatomy of certain Onagraceæ.  
 C. E. BESSEY: The point of divergence of Monocotyledons and Dicotyledons.  
 L. M. UNDERWOOD and F. S. EARLE: Notes on the pine-inhabiting species of *Peridermium*.

MARY A. NICHOLS: Studies in nuclear phenomena, and the development of the ascospores in certain Pyrenomycetes.

H. BAILEY: Remarks on the northern species of *Vitis*.

ALEX. P. ANDERSON: On the formation and distribution of abnormal resin ducts in Conifers.

ARMA A. SMITH: The development of the cystocarp of *Griffithsia bornetiana*.

C. L. POLLARD: On an apparently undescribed *Cassia* from Mississippi.

B. M. DUGGAR: A bacterial disease of the squash bug (*Anasa tristis*).

C. R. BARNES: What is the bark?

N. L. BRITTON: Some Cyperaceæ new to North America, with remarks on other species. On the Cardamines of the *C. hirsuta* group. Notes on the genus *Amelanchier*.

L. H. PAMMEL: Grasses of Iowa.

W. A. KELLERMAN: Ceres-Pulver, Jensen's new fungicide for the treatment of smut.

JOHN K. SMALL: The relation between the genera *Polygonella* and *Thysanella*, as shown by a hitherto unobserved character. An apparently undescribed species of *Prunus* from Connecticut. The flora of the summit of King's Mountain and Crowder's Mountain, North Carolina.

DAVID F. DAY: Parthenogenesis in *Thalictrum fendleri*.

ELIAS J. DURAND: Notes on the family *Pezizaceæ* of Schröter.

S. M. TRACY: What should constitute a type specimen.

F. C. NEWCOMBE: Rheotropism and the relation of response to stimulus.

HERMANN VON SCHRENK: Some adaptation of shore plants to respiration.

D. T. MACDOUGAL: Reaction of leaves to continual rainfall. Influence of rainfall upon leaf forms. The mechanism of curvature in tendrils.

#### SECTION H. *Anthropology.*

HORATIO HALE: Indian wampum records.

W. J. MCGEE: Seri stone art. The beginning of zoöculture.

DANIEL G. BRINTON: Resolution upon the appointment of a committee to report on "The Ethnography of the White Race in the United States." The psychic source of myths.

W. M. BEAUCHAMP: Onondaga games. Aboriginal occupation of New York.

W. W. TOOKER: Meaning of the name Manhattan.

A. F. CHAMBERLAIN: Kootenay Indian place names. Kootenay Indian names of implements and instruments.

F. W. HODGE: Clan system of the Pueblos.

FRANZ BOAS: The limitations of the comparative method in anthropology.

J. McKEEN CATTELL: Physical and mental measurements of students of Columbia University.

FRANZ BOAS: Anthropometry of the Shoshone Indians.

FRED. STARR: Finger prints of American Indians.

R. G. HALIBURTON: Recent discoveries and discussions as to pygmy races.

W. J. MCGEE: The Papago time concept.

FANNY D. BERGEN: Notes on the theological development of one child.

HARLAN I. SMITH: Certain Shamanistic ceremonies among the Ojibways.

ALICE C. FLETCHER: Notes on certain beliefs concerning will power among the Siouan tribes.

M. H. SAVILLE: The temple of Tepoztlan, Mexico.

HARLAN I. SMITH: The preservation of local archæological evidence.

GEORGE V. REICHEL: Character and food.

GATES P. THURSTON: Shell gorgets and ceremonial implements. A ceremonial flint implement and its use among the ancient tribes of Tennessee.

DAVID P. BARROWS: Some Indian rock and body painting in Southern California.

F. W. PUTNAM: Recent explorations in Honduras by the Peabody Museum.

HENRY C. MERCER: Result of recent cave exploration in the Eastern United States.

H. W. SMITH: Finland vapor baths.

FRANZ BOAS: Cupped stones.

F. W. HODGE: Pueblo Indian clans.

JAMES MOONEY: Mescal plant and rite.

AM. JOUR. SCI.—FOURTH SERIES, VOL. II, NO. 10.—OCTOBER, 1896.

SECTION I. *Social and Economic Science.*

JAMES A. SKILTON: The proposed sociological institution.

AARON B. KEELER: The value of social settlement.

MARY J. EASTMAN: Human reciprocity.

JOHN A. MILLER: Better distribution of forecasts.

A. P. WINSTON: The tin plate experiment.

W. LANE O'NEILL: Suicide legislation.

EDWARD ATKINSON: Crime against labor.

S. F. KNEELAND: Practical studies in horticulture, art and music. Relics of ancient barbarism.

## OBITUARY.

JOSIAH DWIGHT WHITNEY, one of the pioneers among American geologists, died on August 19th aged seventy-six years.

He was born in Northampton, Mass., November 23d, 1819, was graduated at Yale in 1839 and began his active geological work as assistant geologist under Charles T. Jackson on the survey of New Hampshire in 1840, where he was engaged for two years. In 1847 he, with J. W. Foster, was appointed by the United States government to assist Jackson in the geological exploration of the Lake Superior region. After two years this work was committed to Foster and Whitney alone, and the results of their labors were published in 1849, 1850 and 1851 in "Synopsis of the explorations of the Geological Corps in the Lake Superior Land District in the Northern Peninsula" (Washington, 1849), and the "Report on the Geology and Topography of a portion of the Lake Superior Land District in the State of Michigan" (Part I, Copper Lands, 1850; Part II, The Iron Region, 1851).

In 1855 he began geological work in Iowa, associated with James Hall; the results of this survey were published as "Reports on the Geological Survey of Iowa" (2 vols., Albany, 1858-9); the geological part being contributed by Whitney, James Hall furnishing the paleontological volume. Next Professor Whitney undertook the investigation of the lead region in Wisconsin and adjoining territory, the account of which was published in the "Report on the Geological Survey of the State of Wisconsin" (Albany, 1862). In this survey James Hall was also associated with him as paleontologist.

In 1860, at the close of the survey in Wisconsin, Professor Whitney was appointed State Geologist of California. Here he organized and carried out a thorough survey of the topographical, geological and natural history features of the state, and published the results in a series of six volumes entitled "Geological Survey of California" (Cambridge, 1864-70), besides annual reports and papers in the scientific journals, giving accounts of the progress of the survey. This was his most elaborate work and that in which his best powers were shown. During the execution of these local geological surveys he published several works of a more general nature. An English translation of Berzelius's "Use of the Blowpipe" was published in 1845. In 1854 appeared "The Metallic Wealth of the United States



described and compared with that of other countries," the result of extensive travel investigating the mines and mineral regions east of the Mississippi. In 1869 "The Yosemite Guide-Book" was published.

In connection with his investigations in Iowa he held the position of State Chemist and Professor in the Iowa State University for several years from 1855. In 1865 he was appointed Professor of Geology, with charge of the School of Mining and Practical Geology, which position he held at the time of his death. During the year 1869 he took a party of students (Marvine, Gannett, Bridge, and Davis) who were taking the mining course at Harvard, to Colorado, where the summer was spent in exploring and surveying. It was on this expedition that the heights of a number of important peaks back of the Front Range were first correctly determined: among these were Mts. Harvard and Yale, to which these names were then given.

He was fond of books and lavished much expense both in accumulating and binding them. By arrangement with the Faculty of the Museum of Comparative Zoology, Whitney's library of geological works goes to the Museum: it is rich in state and national surveys in the United States, and in statistics and journals on mining in all parts of the world. During the last twenty years of his life his lectures were chiefly on economical geology, but he gave occasional courses on dynamical geology, on the physical geography of the United States, and on the history of geographic discovery.

The death of his wife in Cambridge and his daughter (Mrs. T. Allen) in Paris on the same day (about 15 years ago) was a terrible blow, causing him to withdraw into himself, increasing the isolation of his later years.

He was a man of very positive convictions; retaining views of earlier years little changed by later work, and hence increasingly out of sympathy with various theories of modern geology. He had great linguistic ability, like his brother, William D. Whitney. When about 60, he acquired a good knowledge of Russian, and read not only geological and geographical reports, but modern Russian novels in the original. Prof. Whitney had a remarkable knowledge of music, and accumulated an extensive collection of musical works including orchestral scores of classic compositions. He was a familiar figure at the symphony concerts in Boston and Cambridge with score open before him. A great reader, busy worker, active and alert, until last winter when his health seriously failed. He was an original member of the National Academy of Science, and a member of numerous other scientific societies. The degree of LL.D. was conferred on him by Yale in 1870. Mt. Whitney, in southeastern California, the highest mountain in the United States, outside Alaska, was named in his honor.

GEORGE BROWN GOODE died in Washington on the 6th day of September. Born in New Albany, Ind., Feb. 13th, 1851, he

was early interested in natural history studies, graduated at Wesleyan in 1870, and in the following year took charge of the college museum. His chief scientific work was in ichthyology, and he published numerous works on fish and fisheries. He began his official connection with the Smithsonian Institution in 1873, and from 1874 to 1887 held the office of chief of the division of fisheries. He was U. S. commissioner to the international fishery exhibitions in 1880 at Berlin and in 1883 at London. In the Halifax fisheries commission he was the statistical expert employed by the government, and in 1879-80 he had charge of the fisheries division of the 10th census. In 1877 Mr. Goode was appointed a curator, and in 1881 assistant director, of the National Museum, and in 1888 he became assistant secretary of the Smithsonian Institution, which position he held at the time of his death.

It was in the administration of the internal affairs of the Smithsonian Institution that his great ability and tact as an organizer and executive were displayed. He made himself acquainted with every detail of the complex museum, and was able to speak with authority in such publications as "Plan of Classification for the World's Columbian Exposition" and "Museums of the Future." In his relations with his fellow-workers in science Mr. Goode was liberal in extending both assistance and encouragement to scientific progress, and his loss will be deeply felt by those engaged in the promotion of science both at home and abroad. His publications were numerous, especially in the department of Ichthyology. His latest work (*Ocean Ichthyology*, a treatise on the deep-sea and pelagic fishes of the world, based chiefly upon the collections made by the steamers *Blake*, *Albatross*, and *Fish Hawk* in the Northwestern Atlantic, with an atlas containing 417 figures. 2 vols. Text, pp. 557. Plates, 122. Washington, 1895), published in coöperation with Dr. T. H. Beam, was issued only a short time before his death, and will stand as a lasting memorial of his energy and skill as a naturalist. He was a member of the National Academy of Sciences and of numerous other scientific bodies.

SIR WILLIAM ROBERT GROVE died in August last at the advanced age of eighty-five. Though belonging to the legal profession and having devoted a large part of his life to the law, his contributions to physical science, more especially from 1835 to 1866, were of great value. The "Grove cell" and "the Grove gas battery" are familiar to all workers in physics. His essay on "The Correlation of Physical Forces," which appeared in 1846, has been spoken of as "the first systematic statement of the connections between the different departments of physical phenomena." This essay and that of Helmholtz, of the following year, "may be said to form the starting point of the modern science of energetics, of which the experimental foundation was even then being overhauled and laid still more deeply and stably by Joule."

DR. AUGUST KEKULÉ, Professor of Chemistry at the University of Bonn, died on July 13 at the age of sixty-six years.

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[FOURTH SERIES.]

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ART. XLVI.—*Missourite, a new Leucite Rock from the High-wood Mountains of Montana*; by WALTER H. WEED and LOUIS V. PIRSSON.\*

THE Highwoods form one of the isolated mountain groups of central Montana which rise like islands from the great treeless plains stretching eastward from the slopes of the Rocky Mountain Cordillera, and forming the great basin of the Missouri River. They consist of a group of extinct, greatly eroded volcanoes, and the elevations which now compose the area are formed chiefly of tuffs, breccias, and lava flows resting on Cretaceous sediments, together with intruded stocks or cores of massive granular rocks which represent the former centers of volcanic activity and from which great numbers of dikes radiate outward in all directions.†

In the preparation of a report on the geology of this mountain group it has been found that the body of granular rock forming the core at one of the denuded volcanic centers is composed of a new rock type whose petrologic character is of exceptional interest. As the type, moreover, proves to be of great importance to systematic petrography, it has been thought best to present a brief account of the rock and its mode of occurrence, a more detailed description and the discussion of its geological and petrographical relations being reserved for the report in preparation.

\* By authority of the Director of the U. S. Geological Survey. Field geology and collection of material by W. H. W.; microscopical petrography by L. V. P.

† A sketch of the geological features of the region, with a geological map, has already been published by the authors. Bull. Geol. Soc. America, vol. vi, p. 389, 1895.

The stock or core is situated at the head of Shonkin Creek, a large stream draining the northern part of the mountains. The headwaters of this stream have cut deeply trenched channels through the mountains and have exposed the granular rock. The region, although mountainous, is almost devoid of timber. Smooth grassy slopes with occasional low rock exposures generally prevail.

*Geological occurrence.*—The new rock type described forms a stock of granular rock intrusive in Cretaceous shales and in the fragmental volcanic material which overlies them, both being highly altered near the contact with the igneous mass. These enclosing rocks are cut by a multitude of dikes, radiating from the core as a center and forming the most conspicuous feature of the surrounding country.

The igneous rock forming the stock constitutes an irregular mass  $2\frac{1}{2}$  miles long and in places half as wide. Where covered by the sedimentary strata, the structure simulates that of a laccolith, but careful study showed that the intrusion is not of this character. The igneous rock was in part intruded between the sedimentary rocks and the volcanic breccias which overlaid them, and in part injected along the bedding planes of the sedimentary strata at the edges of the stock. At the south end of the core a coarse agglomerate of massive rock represents the filling of a vent of a volcanic throat, the material of the blocks and cement varying greatly in granularity but consisting essentially of the same type composing the main body of the core.

Constituting beyond all doubt a geological unit, the rock mass of this volcanic stock varies considerably both in coarseness of grain and in the proportion of its constituent minerals. The specimen selected for description and analysis represented the coarsest grained and freshest variety observed.

The rock seldom forms conspicuous exposures; near the contact it is sometimes weathered into castellated masses and pinnacles, but the usual outcrop is low and hidden by the debris blocks into which the rock ordinarily weathers. Platy parting was observed near the contact, but elsewhere the fracture is massive and determined by shrinkage planes.

*Megascopic characters.*—Seen in the outcrop, the rock appears dark gray, coarse grained, and resembles many basic massive rocks in appearance. In the specimen it is seen to be coarsely and evenly granular and to be composed of light and dark constituents, the proportion by bulk being about two of the light to three of the dark minerals. The separation by the heavy fluids shows, however, that by weight the white mineral forms only one-fifth to one quarter of the whole. The distinction in color is strongly marked and gives the rock a mottled mosaic-like appearance.

Upon examination the dark constituents may be distinguished as chiefly a greenish black augite in columnar masses and aggregates which are never idiomorphic, together with an occasional speck of a bronzy brown biotite of ill-defined outline or a grain of a deep yellow olivine. Filling the interspaces between these dark minerals in formless masses is a very pale greenish gray substance which is leucite. The average size of crystal grain varies from 2 to 5<sup>mm</sup>, so that the rock is of quite coarse granular structure, and it resembles most strikingly in fact many coarse-grained gabbros.

*Microscopic characters.*—The thin section under the microscope shows the minerals present to be *apatite*, *iron ore*, *olivine*, *augite*, *biotite*, *leucite*, and some zeolitic products.

The *apatite* and *iron ore*, which are present rather rarely in moderate-sized grains, show nothing of especial interest beyond that they are found enclosed in the other minerals, and the biotite frequently encloses the iron ore.

The *olivine* is extremely fresh, unaltered in any way, and resembles the olivine of fresh gabbros. It contains great numbers of very fine glass and iron ore enclosures. It never shows any crystal faces, but is in rounded, formless, anhedral grains which are frequently enclosed in biotite and augite.

The *augite* is of a pale green color with a tone of brown; it is very fresh and clear, contains enclosures of ore and specks of biotite and is entirely allotriomorphic, though the orientation of the ore grains is at times zonal, thus indicating crystal planes. It has an excellent cleavage and twinning bands pass through it in places; it does not show any pleochroism.

The *biotite* is strongly pleochroic between a deep umber brown and a pale yellow brown; it is also entirely allotriomorphic though apt to surround the other minerals in bands, especially the olivine and iron ore. It is particularly characteristic in such cases that it then passes from brown into an olivine green variety which has a mottled, somewhat stringy, fibrous appearance. It appears in these cases as if the brown variety had suffered from some magmatic process; it does not seem to be due to any ordinary process of weathering.

*Leucite.*—The leucite appears also like the other minerals in formless masses filling the interspaces between other minerals. It is perfectly clear and free from all inclusions, except now and then a grain of the ferromagnesian minerals. Between crossed nicols it shows most beautifully the cross-banded twinning structure so characteristic of leucite. It is in general perfectly clear, limpid and fresh, though in some areas, in delicate fringes along cracks and on the borders of grains, a low birefracton shows that processes of zeolitization have commenced. This will be described more in detail later.



As the presence of actual leucite itself has never before been demonstrated, so far as we know, in a granular plutonic rock, it became a matter of importance to prove its identification beyond all doubt.

For this purpose a considerable portion of the rock was crushed, sifted, washed, and treated with the potassium mercuric iodide solution. Immediately all of the ferro-magnesian minerals sank, leaving the white component floating. On then lowering the specific gravity by dilution, nothing except an occasional grain fell until 2.465 was reached, when a very little of the white powder came down. This under the microscope proved to consist of isotropic grains with attached particles of pyroxene and biotite which had evidently increased their specific gravity. This behavior of the rock powder in the heavy solution proves the absence of all feldspars and nephelite, thus confirming the microscopic examination. On now lowering the specific gravity of the liquid to 2.405, the great bulk of the white component came down, leaving a small portion floating. The average specific gravity of this material may be taken as 2.44. Examined under the microscope it was found to be a very pure product, consisting of clear isotropic grains which here and there showed a faint birefracton. An analysis of it (by L. V. Pirsson) gave the following results:

|                                      |       |       | Molecular ratios.  |
|--------------------------------------|-------|-------|--------------------|
| SiO <sub>2</sub> -----               | 54.46 | .907  | } .907 = 4.12 = 4. |
| Al <sub>2</sub> O <sub>3</sub> ----- | 22.24 | .216  |                    |
| Fe <sub>2</sub> O <sub>3</sub> ----- | .68   | .004  |                    |
| MgO -----                            | trace | ----- | } .220 = 1. = 1    |
| CaO -----                            | .10   | .002  |                    |
| K <sub>2</sub> O -----               | 18.86 | .200  |                    |
| Na <sub>2</sub> O -----              | .70   | .011  |                    |
| H <sub>2</sub> O -----               | 2.29  | ----- |                    |
| <hr/>                                |       |       |                    |
| 99.33                                |       |       |                    |

The formula is therefore  $KAl(SiO_3)_2$  and the mineral is consequently leucite. There appears to be a very slight deficiency of alkalis, and this may be due in part to replacement by water, whose presence is undoubtedly due to processes of zeolitization which are commencing and which may be in part the cause of the faint birefracton noticed above. The small amount of soda shows the leucite to be a very pure potash compound. So far as we know, this is the first analysis of a leucite from other than an Italian locality, with the exception of that given by Steinecke\* of the mineral from Choi in Persia.

\* Jüngere Eruptivgesteine aus Persien, Inaug. diss., Halle, 1887, p. 12.

*Zeolitization and a probable new zeolite.*—The small portion of powder which was left floating in the heavy solution after the precipitation of the leucite at 2·405 was found to come down gradually as the specific gravity was lowered. At 2·357 much had already fallen. At 2·30 a small portion was still floating, and this was then thrown down and analyzed, in the hope of learning what the character of the zeolitization mentioned above had been. Examined under the microscope it was found to consist of isotropic grains, presumably analcite, mingled with a substance of low birefractation. The amount of material was less than ·4 gram, and of this one-tenth gram was taken for the determination of water.

The analysis (by L. V. Pirsson) gave the following results:

|                                      |        |      | Ratios. | A.   | B.   |
|--------------------------------------|--------|------|---------|------|------|
| SiO <sub>2</sub> .....               | 50·18  | ·836 | ·836    | 4    | 3·46 |
| Al <sub>2</sub> O <sub>3</sub> ..... | 25·07  | ·243 | ·243    | 1·16 | 1    |
| Fe <sub>2</sub> O <sub>3</sub> ..... | trace  | ---- |         |      |      |
| CaO.....                             | 1·70   | ·030 | ·224    | 1·06 | ·93  |
| Na <sub>2</sub> O.....               | 6·53   | ·105 |         |      |      |
| K <sub>2</sub> O.....                | 8·36   | ·088 |         |      |      |
| H <sub>2</sub> O.....                | 9·02   | ·501 | ·501    | 2·39 | 2·06 |
| Total                                | 100·86 |      |         |      |      |

The substance dissolved readily in acid with separation of gelatinous silica. The ordinary analytical errors are of course somewhat magnified by the small quantities operated upon, but as great care was taken it is not believed they are sufficient to affect the ratios. In the first column under A one-quarter of the silica is taken as unity, under B the alumina is taken as unity. It will be seen that the ratio of the protoxides to the sesquioxide to the water is 1:1:2, as demanded by the analcite formula, but that there is a deficiency of silica. The microscope having already shown that two substances are present, one of them isotropic and most probably analcite, if we consider the soda present as forming that mineral and deduct sufficient silica, water and alumina to make with it analcite, the remainder reduced to 100 becomes:

|                                      | Found. |      | Ratios. |      | Calculated. |
|--------------------------------------|--------|------|---------|------|-------------|
| SiO <sub>2</sub> .....               | 45·85  | ·764 | ·764    | 3·01 | 3 44·6      |
| Al <sub>2</sub> O <sub>3</sub> ..... | 26·07  | ·253 | ·253    | 1    | 1 25·6      |
| CaO.....                             | 3·12   | ·056 | ·218    | ·86  | 1 3·4       |
| K <sub>2</sub> O.....                | 15·35  | ·162 |         |      |             |
| H <sub>2</sub> O.....                | 9·61   | ·534 | ·534    | 2·11 | 2 8·9       |
|                                      | 100·00 |      |         |      | 100·0       |

This yields approximately the formula  $(K_2Ca)Al_2Si_3O_{10} \cdot 2H_2O$ , which is exactly that of a natrolite  $Na_2Al_2Si_3O_{10} \cdot 2H_2O$ , in which potash and lime have replaced soda. The ratio of  $CaO : K_2O$  is 1:2.91 or almost exactly 1:3, and the theoretical composition of such a compound ( $K_6Ca Al_3Si_{12}O_{40} \cdot 8H_2O$ ) is given above in the column to the right, and it can be seen that the agreement with the amounts obtained is moderately close. If, on the other hand, we assume that the potash yielded by the analysis belongs to leucite and consider it the isometric mineral, then the soda and lime would belong to a mesolite-like mineral, but in that case the agreement of the ratios is very poor and the water entirely too high. The material also floated at a specific gravity of 2.30 and was thrown down below this, which should have excluded leucite, if present in the proportion the amount of potash would indicate. It is reasonable to suppose also that the zeolitization of leucite would yield a potassic compound and not a sodium one. Taking into consideration the mathematical chances against the improbability of the above ratios being accidental and the natural chemical possibility of a potash molecule similar to natrolite, it is not unreasonable to infer that we have a potash zeolite of the natrolite type in this rock.

In thin section this zeolite is seen as small feathery particles of low birefracton running in narrow bands around the leucites and along fractures; it evidently attacks the mineral from the outer surfaces. In places where it has grown into considerable areas, the areas, while they extinguish as units, are seen to be composed of a curious grouping of two substances in winding, interlaced, vermicular forms almost exactly like micrographic intergrowths of quartz and feldspar, but excessively fine. Of these two substances one is birefractive, the other isotropic, and from what has already been said it seems probable that they are a mixture of the potash zeolite with analcite.

Occasional separate isotropic grains also occur, which do not show the cross-banded twinning of the leucite, and these are supposed to be also of analcite.

*Chemical composition.*—A mass analysis of the rock has been made for the U. S. Geological Survey laboratory by Mr. E. B. Hurlburt of the Sheffield Scientific School, which gave the following results (average of two):



|                                      | I.     | II.    | III.   | IV.   | Ia.  |
|--------------------------------------|--------|--------|--------|-------|------|
| SiO <sub>2</sub> .....               | 46.06  | 47.28  | 46.73  | 44.35 | .767 |
| Al <sub>2</sub> O <sub>3</sub> ..... | 10.01  | 11.56  | 10.05  | 10.20 | .097 |
| Fe <sub>2</sub> O <sub>3</sub> ..... | 3.17   | 3.52   | 3.53   | 13.50 | .020 |
| FeO .....                            | 5.61   | 5.71   | 8.20   |       | .078 |
| MgO .....                            | 14.74  | 13.17  | 9.68   | 12.31 | .391 |
| CaO .....                            | 10.55  | 9.20   | 13.22  | 11.47 | .188 |
| Na <sub>2</sub> O .....              | 1.31   | 2.73   | 1.81   | 3.37  | .021 |
| K <sub>2</sub> O .....               | 5.14   | 2.17   | 3.76   | 4.42  | .054 |
| H <sub>2</sub> O .....               | 1.44   | 2.96   | 1.24   | ?     | .080 |
| TiO <sub>2</sub> .....               | .73    | .88    | .78    | ?     | .009 |
| P <sub>2</sub> O <sub>5</sub> .....  | .21    | .59    | 1.51   | ?     |      |
| MnO .....                            | trace. | .13    | .28    | ---   |      |
| BaO .....                            | .32    | ?      | ?      | ?     |      |
| SrO .....                            | .20    | ?      | ?      | ?     |      |
| SO <sub>3</sub> .....                | .05    | ---    | none.  | ---   |      |
| Cl .....                             | .03    | .18    | .18    | ---   |      |
|                                      | <hr/>  | <hr/>  | <hr/>  | <hr/> |      |
|                                      | 99.57  | 100.08 | 100.97 | 99.62 |      |
| Cl = O                               | <hr/>  | <hr/>  | <hr/>  | <hr/> |      |
|                                      | .01    | .04    | .04    |       |      |
|                                      | <hr/>  | <hr/>  | <hr/>  | <hr/> |      |
|                                      | 99.56  | 100.04 | 100.93 |       |      |

- I. Missouriite, head of Shonkin Creek, Highwood Mountains, Montana. E. B. Hurlburt, analyst.
- II. Leucite absarokite (Hague, this Jour. vol. xxxviii, p. 43, 1889. Iddings, Jour. Geol., vol. iii, p. 938, 1895. J. E. Whitfield, analyst.
- III. Shonkinite, Square Butte, Highwood Mountains (Bull. Geol. Soc. Amer., vol. vi, p. 414, 1895). L. V. Pirsson, analyst.
- IV. Leucite basalt, Bongsberg by Pelm Eifel (Hussak 77 Bd Sitzb. K. Akad. Wiss. Wien I Abt. 1878). E. Hussak, analyst.
- Ia. Molecular ratios of No. I.

This analysis brings out strongly the leading characteristics of the rock, its very high lime, iron and magnesia, which have compelled the formation of such quantities of pyroxene and olivine; the predominance of potash over soda, which with the low silica have conditioned the formation of the leucite, and which explains also why no feldspars have formed.

The endeavor to compare this rock chemically with the effusive leucite basalts, of which it forms the plutonic representative, has not been entirely satisfactory owing to the lack of accurate and complete analyses of them. A number of analyses exist but are deficient in important determinations, and in some cases it is clear, from what is stated concerning the mineralogical composition, that the separation of the magnesia and alumina is inaccurate, the magnesia being in part thrown down with the

alumina. This is unfortunately an all too common error in rock analyses. One of the best is shown in the above table in No. IV, and it will be seen that the agreement is good in the essential details. In No. II is given one of the absarokites of Iddings, with which the missourite, from a chemical point of view, seems to be closely related. In No. III is shown the composition of the shonkinite from the same mountain group. With the same amount of silica in each, the lower alkalis of the shonkinite have permitted orthoclase to form as the dominant white mineral, while their higher amount in the missourite has produced leucite in its place. In the shonkinite the excess of the alumina over the alkalis has gone into the augite and biotite, and the same is undoubtedly true in the missourite. Taking into consideration the ratios shown by the analysis, the separations by the heavy liquid and the study of the section, the rock has approximately the following mineralogical composition :

|                |       |
|----------------|-------|
| Iron ore ..... | 5     |
| Augite .....   | 50    |
| Olivine .....  | 15    |
| Biotite .....  | 6     |
| Leucite .....  | 16    |
| Analcite ..... | 4     |
| Zeolites ..... | 4     |
|                | <hr/> |
|                | 100   |

*Structure.*—The structure is purely granitoid, but is not hypidiomorphic since no mineral shows any crystal planes, but all are wholly allotriomorphic. The iron ore, apatite and olivine commenced forming before the other minerals, but are in rounded anhedral grains; the augite and leucite were crystallizing contemporaneously, as shown by the fact that each encloses grains of the other. In plain light the rock section appears precisely like those of many coarse-grained, massive gabbros, and it is not until the nicols are crossed that it is perceived that the colorless areas are not composed of striated plagioclase but of isotropic leucite.

The relations of the minerals are shown in the accompanying figure.

*Classification.*—It is clear from what has been said in the foregoing that this rock is a new type, and it fills a place which has hitherto been vacant in all systems of rock classification in which either the texture, structure and granularity of rocks or their geological mode of occurrence is taken into account. It is the massive, granular, plutonic representative of the leucite basalts and bears the same relation to them that gabbro bears to

the ordinary plagioclase basalts or granite to rhyolite. It is closely related to theralite, shonkinite, and ijolite, but cannot be classed under any of these types and must therefore be dis-



Micro-drawing of Missouriite  $\times 6$ ; P = pyroxene, O = olivine, b = biotite  
L = leucite.

tinguished by a special name of its own. We have therefore called it *missourite* from the Missouri River, the most prominent and best known geographical object in the region where it occurs.

Washington and New Haven, May, 1896.



ART. XLVII.—*The Silveria Formation*; by OSCAR H. HERSHEY, Freeport, Ill.

IN a recent number of the *American Geologist*,\* the writer discussed, under the name of "Kansan Buried Loess," a small series of blue and brown laminated silts, exposed in a ravine one and one-half miles south of the city of Freeport, Stephenson county, Illinois. At the time, this one very limited exposure furnished the only definite information of this formation which had been secured. Subsequent studies, however—carried on chiefly through the examination of well-sections—have shown this formation to be an unusually important one, not only from its bulk, but also from the light which it throws on the relative altitude of northwestern Illinois during the earlier portion of the Kansan epoch. It has, therefore, been thought advisable to again place the subject before the geologic public, and this paper may be considered as a preliminary description and definition of the formation.

The fact is, of course, known to the writer that buried silts, nearly identical in lithologic constitution and stratigraphical position, have been discovered in several counties in northern Illinois, and also in that portion of Iowa which closely adjoins this area. But as there is always more or less uncertainty connected with the correlation of buried silts in different areas when their direct continuity has not been traced, and as this formation appears to be best developed in Stephenson county, Illinois, I will confine my remarks to that section of country exclusively.

The *Silveria* formation is a thick bed of stratified silt of a nearly uniformly dark bluish-gray color, and which occupies and nearly fills the deep-buried portion of the Pecatonica valley and its tributary valleys in northwestern Illinois. It is penetrated by nearly all the wells in the vicinity of the present streams, and is popularly known as "blue clay." It is, however, not a true clay as it does not contain the necessary percentage of exceedingly fine particles. This statement leads us directly to the manner of discriminating it from blue till or boulder clay, which is sometimes penetrated by wells in this same district. The blue till is lighter in color, more calcareous and finer-grained, presents no evidences of stratification, and contains irregularly disseminated and comparatively abundant pebbles and small boulders largely of foreign rock species. The blue silt differs from it chiefly in the following particu-

\*Early Pleistocene Deposits of Northern Illinois. *Am. Geol.*, vol. xvii, No. 5, May, 1896.

lars: Besides its usually very dark blue gray or blue brown color, there are bands several feet in thickness which are of a lighter tint. These are encountered in contiguous well-sections at about the same depth, indicating apparently horizontal stratification. Microscopically, the deposit is a very fine-grained sand or silt, with many of the particles angular and sub-angular (one of the distinguishing characteristics of a *loess*). It usually contains a few sparsely disseminated rock fragments of small size, and they have so far, except in the extreme lower portion of the formation, proven to be *exclusively of angular white chert*. Near the base, in the deeper valleys, there are, interstratified with the blue silt, thin strata of fine gravel, composed mostly of the angular chert fragments with a few Canadian pebbles. The blue color dominates this formation so completely that even this gravel is stained with a blue tint, thereby enabling us to readily discriminate it from another gravel formation buried in the valleys, but which is of a bright red and reddish-brown color. Certain thin layers of the blue silt are, also, thickly packed with sharply angular white chert fragments which probably reached their present position through the agency of floating ice. Not only is this great preponderance of angular fragments of white chert, and almost total absence of the ordinary drift pebbles, of the greatest aid in distinguishing the presence of this formation in the material brought up by the sand pump, but it is believed also to indicate that the area in which the deposit occurs had not previously been glaciated. The white chert is of local derivation, being contained abundantly in the residual material over the Galena and Niagara limestones, the terranes chiefly exposed in northwestern Illinois.

At the single surface exposure in this county, so far as at present known (described in the paper already mentioned), the *Silveria* formation, besides displaying all the characteristics discovered in well-sections, is laminated in the irregular manner commonly known as "ripple marking." The upper two feet are false-bedded, ferruginous, light-brown, fine sand and silt, and appear to represent the shore deposit of the ancient lake in which this formation was laid down. It is here sparingly fossiliferous. There are, uniformly disseminated and apparently largely responsible for the blue color, minute particles of carbon. In addition, also, the fossil flora is represented by very diminutive fragments of black semi-decayed wood. But the only interesting portion of the fossil contents consists of several species of small shells. These occur pretty generally distributed through the exposed portion of the deposit in the proportion of several hundreds to every cubic foot of silt. But in the upper division, described above as representing

apparently a shore or just off-shore deposit, they increase in proportionate numbers. This division of the formation had not been exposed previous to a heavy flood which occurred during this spring, and the fossil contents of the formation had not been professionally studied at the time of the preparation of the previous paper on the subject. Lately, however, several collections from this horizon have been made and submitted to Mr. W. H. Dall, whose report is as follows:

"No. 1 is probably a variety of *Pyramidula striatella* Auth. It is larger, better-developed, and less rugose below than the recent specimens with which I have compared it. No. 2 appears to be *Pupa blandi* Morse, though a young shell mixed with the others may be *Vertigo ovata* Say. No. 3 is *Succinea avara* Say; a fragment of a *Helix*, like *H. tridentata* Say, was intermingled. There is nothing depauperate about the specimens."

The three species undoubtedly present are represented by about the following proportionate numbers of individuals: *S. avara*, 50, *P. blandi*, 5, and *P. striatella*, 2. They are practically a portion of the ancient terrestrial fauna of the neighborhood, and with this fact in mind the significance of their increase in numbers in the apparent shore deposit becomes readily apparent. The number of species is too limited to warrant our drawing very definite conclusions from them as to the nature of the climate of that time. Their rather robust development would seem to negative the idea of a cold climate, but the presence of the ice-sheet in Illinois necessary to the supply of material for the formation of this deposit, undoubtedly introduced a cooler climate than the present. I have previously held to the position that the comparative scarcity of the faunal and floral remains enclosed within this deposit, which was peculiarly favorable for their preservation, may be considered as indicating the relative severity of the climate.

The position of the Silveria formation in the county of Stephenson may be briefly described as follows: Just previous to the opening of the Kansan epoch, the streams of northern Illinois flowed at the bottom of narrow, steep-sided cañons, trenched from 300 to 400 feet below the general upland surface. The first important effect of the approach of the advancing Kansan ice-sheet was to depress this area and cause a silting up of the deep valleys. In Stephenson county the cañon valleys were about half filled with fine gravel and blue silt. This has since suffered great erosion and has been buried deeply under later formations. It is now quite frequently penetrated by wells along the valley sides, but at heights which never exceed 20 feet above the present river level at Freeport. Nearer the



center of the valleys it is almost invariably reached at about 20 feet under the present stream level. Being a stiff, clay-like silt, but slowly pervious to water, all wells upon encountering it must go to the bottom, where a supply of water may be obtained from the basal gravel or from fissures in the solid rock below. In thickness it usually varies at present between 40 and 60 feet, but is occasionally penetrated to the depth of 100 feet. Over the abandoned valley of Yellow Creek about 3 miles S.W. of Freeport, there is a low ridge of drift. A well beginning on this ridge was sunk 183 feet without reaching the solid rock at the bottom of the valley. The deposits passed through were first, brown loam, followed by drift, beneath which "blue clay" was reported to have been penetrated to the thickness of 150 feet. This "blue clay" represents the Silveria formation, which fills up the abandoned valley of Yellow Creek to above the present stream level.

The frequency with which the blue silt is encountered at the height of 20 feet above the present stream level, along the sides of the valleys, shows that, were the later formations stripped from the region, they would be found to have rested upon narrow terraces, bounding on either hand trough-shaped valleys about 40 feet in depth. The horizontal banding, the horizontality of the stratification at the exposure near Freeport and other phenomena connected with the formation, have been considered to indicate that the buried terraces represent the nearly level surface of the deposit when completed. In those portions of northwestern Illinois which are outside of the Pecatonica basin, the deposition of the buried blue silt was probably due solely to subsidence of the land, but in Stephenson county we can explain its unusual development only under the supposition that the Pecatonica valley was closed on the east by a glacier, thus raising the water level considerably above that which the mere subsidence of the region would have done. The probable existence of this extra-glacial lake somewhat complicates the subject, but still it is believed that the valleys in the surface of the silt are valleys of erosion. Not only do these valleys show erosion forms, but they are in proportionate size to the present streams, and are never accidentally partially closed by a strong development of the blue silt. Moreover, erosion is clearly indicated in the exposure near Freeport. In short, the evidence is sufficiently strong to warrant my assumption of their origin as valleys of erosion. Therefore, I shall consider the formation to have originally extended over the central portions of the valleys to practically the same height which it now attains on their sides.

If the importance of the formation be judged by its bulk it will be seen to compare favorably with all the others of the

district. It underlaid one-seventh of the county with an average original thickness of 100 feet. This spread out over the entire county would make a uniform layer of 14+ feet. For the purpose of comparison I will introduce a table in which all the other Quaternary formations of the county have been treated in the same manner.

|   | Thickness if spread<br>over entire county. |
|---|--|
| 1. Silveria formation .....   | 14 + feet.                                 |
| 2. Lake Pecatonica formation.....   | 1 foot.                                    |
| 3. Till.....  | 4 feet.                                    |
| 4. Stratified drift gravel.....   | 2 feet.                                    |
| 5. Angular limestone gravel (drift).....                                    | 1 foot.                                    |
| 6. Florencia formation.....   | 6 inches.                                  |
| 7. Valley loess.....  | 2 feet.                                    |
| 8. Upland loess.....  | 7 feet.                                    |
| 9. Modern alluvium .....  | 10 + inches.                               |
| Superficial deposits of Stephenson County, Ill. Total 32 feet,<br>4 inches. |  |

Its mass is thus seen to be twice as great as the drift series proper (Nos. 3, 4 and 5) and about one and one-half times as great as the combined mass of the Iowan *loess* series of the region (Nos. 6, 7 and 8.)

The determination of the exact age of the Silveria formation depends on several factors, the precise value of which cannot at present be positively demonstrated. The first is the positive identification of the drift sheet which overlies this formation with that which is exposed in Kansas, and therefore known as the Kansan drift sheet. For reasons which it is hardly necessary to mention here, the oldest drift sheet of northwestern Illinois, southwestern Wisconsin and northeastern Iowa, has been considered as Kansan in age. Moreover, it is supposed to represent the culminating stage or time of maximum advance of the great Kansan ice-sheet. As this correlation is probably correct, I shall assume that the drift sheet of Stephenson County, Illinois, is Kansan in age. Now this drift-sheet rests upon the Silveria formation. Therefore, the age of the latter is not later than the Kansan epoch. Following the usual custom of correlating all formations which are inter-glacial in position, with the inter-glacial epochs, I should pronounce this deposit as a pre-glacial formation. But its evident derivation from material formed during glacial action and (presumably at least) the known position of the glacial front during its deposition, connect it with some stage of glaciation. Therefore, it is neither properly pre-glacial nor inter-glacial in age.

The second factor which creates a difficulty in placing this formation in the geologic time scale, is the exact significance of the eroded valleys in the surface of the blue silt. The drift sheet in the deeper valleys has been mostly removed by subsequent erosion (Aftonian mainly). But locally we find the drift in situations which indicate that the erosion of the valleys in the blue silt was accomplished mainly before the completion of the Kansan epoch. The question remains, however, as to whether this erosion was sub-aerial or glacial in nature. In the exposure near Freeport it is settled in favor of the former hypothesis, for here we find an erosion unconformity with a slightly developed soil and remains of vegetation at its surface, overlain by another extra-glacial lake deposit which itself preceded the arrival of the ice in that vicinity. Strong presumptive evidence that the erosion of all the valleys in the surface of the blue silt was mainly sub-aerial and antedated the arrival at Freeport of the ice-sheet, is furnished by the regularity of the valleys, their nearly uniform depth, and the absence from the till west of Freeport of any large amount of material which could have been derived from this formation. Therefore, we can say that if these valleys are truly valleys of erosion as they appear to be, their excavation was accomplished mainly by sub-aerial agencies, and antedated the glaciation of the region.

It has been assumed, as before stated, that the unusual development and relatively great height which the Silveria formation attains in Stephenson County, was due to obstruction of the valley by the advancing ice-sheet. The sub-aerial erosion within the limits of the former lake area, above partially demonstrated, requires the disappearance of the ice from the lower portion of the valley to give free drainage through the ancient Rock-Illinois valley, then occupied by the ancestor of the present Rock river. The relative importance of this fluctuation in the border portions of the ice-sheet depends largely on the length of the erosion interval above indicated. While the amount of material removed from the immediate vicinity of the streams during this post-Silveria erosion interval was apparently greater than the erosion which has been accomplished in the same position since the Iowan loess series was deposited, I do not think that any very long period was required. Although the completion of the work within 500 years would have converted the ancient Pecatonica river into a stream of "liquid mud," the somewhat increased precipitation of the glacial period, and otherwise more favorable conditions of erosion, may have enabled its accomplishment.\*

\* The length of time required to deposit the Silveria formation in Stephenson County can only of course be conjectured. If we assume the annual amount of sediment deposited to have had a thickness of one inch, and the average original



The post-Silveria erosion interval has no epochal value, as it was too short, there is no evidence of a marked change of climate, and the ice-sheet probably lay close to the Rock-Illinois valley during the entire time. I should divide the Kansan epoch into a number of sub-epochs or stages of which the time of deposition of the Silveria formation would constitute one stage, the post-Silveria erosion interval another, and the time of glaciation of northwestern Illinois still another. Therefore, the Silveria formation in Stephenson County, Illinois, may be chronologically correlated with an early stage of the Kansan epoch.

The post-Silveria stage of erosion has some bearing on the question of the relative altitude of the region at that time. All the deposits in the valleys of Stephenson County, under the drift sheet and its associated Lake Pecatonica clays, except the Red Gravel before referred to, appear to be genetically connected so that they may be considered as one formation, made up of gravel, sand, and mainly of blue silt—the Silveria formation. Just previous to the beginning of deposition of this formation, the streams flowed from 100 to 200 feet lower than at present. Therefore, the land stood relatively higher. During the post-Silveria stage of sub-aerial erosion, when free drainage was again restored in the Pecatonica basin, the streams flowed about 20 feet under the present water level or over 100 feet above the pre-Silveria stream level. The comparatively great width of the post-Silveria valleys indicates that the interval of erosion was sufficiently prolonged to enable the streams to cut to at least a local base level. Therefore, the land stood relatively lower at the close than it did at the beginning of the Silveria sub-epoch. In other words, the early stages of the Kansan epoch were characterized by a slow subsidence of the land which had returned nearly to its present relative altitude before the maximum extension of the ice-sheet.

The name which I have proposed for the formation discussed in this paper, is derived from that portion of Stephenson county, where it is, so far as at present known, best developed, and in which its only surface outcrop in the Pecatonica basin, occurs. If the deposit in this county should be correlated with some formation already discriminated and specifically designated in other districts, the name of the latter would, of course, have precedence, but the term *Silveria* would still be of some value as a local denomination of the conditions peculiar to the Pecatonica basin, namely as *Lake Silveria*.

Freeport, Ill., July 13, 1896.

thickness of the formation to have been 100 feet, 1,200 years would be required. This estimate probably falls rather below than above the actual time.

ART. XLVIII.—*On the Viscosity of Mixtures of Liquids*; by  
C. E. LINEBARGER.

I. *Historical. Object of Investigation.*

THE earliest investigations of note on the viscosity or internal friction of solutions were carried out by Girard\* and Poiseuille.† “The isolated discovery of M. Poiseuille, that diluted alcohol has a point of maximum retardation, coinciding with the degree of dilution at which the greatest condensation of the mixed liquids occurs,” induced Graham‡ to investigate mixtures of other liquids with water as regards their rate of transpiration, as this appeared to him “to depend upon chemical composition, and to afford an indication of it.” He made a number of determinations of the internal friction of aqueous solutions of nitric, sulphuric, acetic, butyric, valeric, formic, and hydrochloric acids, as well as of ethyl alcohol and acetone, finding that usually a maximum of the property in question was observable. “It is remarkable,” he writes, “that hydrated liquid compounds appear in general to show only one decided transpiration maximum, as with the 1-hydrate in sulphuric acid, the 2-hydrate in acetic acid, the 3-hydrate in nitric acid, the 6-hydrate in alcohol, and the 12-hydrate in hydrochloric acid.”

Wijkander§ determined the viscosity of mixtures of acetic acid and water, aniline and benzene, ether and chloroform, ether and carbon bisulphide, ether and alcohol, and benzene and alcohol at temperatures between 0° and 60°. His results for the mixtures of water and acetic acid corroborated those by Graham for the same mixtures as regards the occurrence of a maximum of the property in question; the position of this maximum, however, varied with the temperature at which the determinations were carried out, a relation of any definiteness between chemical constitution and viscosity seeming not to exist. Mixtures of such of the liquids employed by Wijkander as were composed of normal molecules were found not to exhibit a maximum of the property in question; generally

\* *Mouvement des fluides dans les tubes capillaires*, Mémoires de l'Institut, 1813, 1814, 1815 and 1816.

† *Recherches expérimentales sur le mouvement des liquides dans les tubes de très petits diamètres*, Annales de Chimie et de Physique, III, vii, p. 50, and xxi, p. 76, 1848; also in Pogg. Ann., lviii, 424, 1843.

‡ *On the Capillary Transpiration of Liquids in Relation to Chemical Composition*, Chemical and Physical Researches, p. 601; and Philosophical Transactions, 1861, pp. 373–386.

§ *Ueber die Reibung der Flüssigkeiten*, Lunds. Physiog. Sölsk Jubelskrift, 1878; Wied. Beiblätter, iii, 8, 1879. Only the reference in the “Beiblätter” has been accessible to me.

they had a less degree of fluidity than that calculable by the rule of mixtures, and, in the case of the mixtures of ether with chloroform and carbon bisulphide, points of inflection were present in the curves representing the phenomena.

Pagliani and Battelli\* made some determinations at 0° and 10° of the internal friction of mixtures of methyl, propyl, and ethyl alcohols with water. They discovered that these mixtures all presented a maximum in viscosity, but that "La ricchezza procentica alla quale corrisponde il massimo di attrito diminuisce col crescere della temperatura, per cui si ha ragione di credere che ad una data temperatura non si abbia poi questo massimo, ma che il coefficiente di attrito delle mescolanze alcooliche vada continuamente crescendo col crescere della proporzione di alcool in esse contenute."

As a continuation of the work of these Italian physicists may be considered the investigations of J. Traube,† who determined the viscosities of a number of aqueous solutions of several of the organic acids and alcohols.

S. Arrhenius‡ also has measured the fluidity of some organic liquids dissolved in water; his solutions were dilute, containing 10 per cent or less of the dissolved liquid; he observed that usually the viscosity of water is increased by the addition of small proportions of non-electrolytic liquids, but, in a foot note, states that a little acetone, ethyl ether, or methyl alcohol, when added to ethyl alcohol, lowers the degree of viscosity.

An inspection of the determinations of the viscosity of liquids recorded in the papers just mentioned brings to light the fact that all mixtures, which have a maximum of internal friction, contain at least one liquid which is known to be composed of associated molecules; also, that such mixtures as do not present this maximum are made up of normal liquids. It seems legitimate to infer, then, that there is an intimate relationship between the occurrence of a maximum of viscosity in liquid mixtures and the molecular polymerization of the liquids composing them; indeed, it may be said that it is probable that the maximum will be found only in such mixtures as contain associated liquids. Another circumstance which increases the probability of this statement is the fact that the higher the temperature, the less pronounced the maximum, and also, as is well known, the less the degree of molecular complexity. The curves given in Traube's paper are instructive in this respect; they are drawn with concentrations of the axis

\* Sull'attrite interno nei liquidi, Annali del R. Istituto Tecnico Germano Sommeiller in Torino. XIII. Anno, 1884-1885.

† Ueber die innere Reibungsconstante und die spezifische Zähigkeit organischen Flüssigkeiten und ihrer wässerigen Lösungen, Ber. deutschen chem. Gesell., xix, 871-892, 1886.

‡ Zeitschr. f. phys. Chem., i, 284, 1887.



of abscissas and viscosities on the axis of ordinates for mixtures of water with some of the alcohols of the fatty series, and include the data communicated by Pagliani and Battelli. An inspection of them shows that the most considerable maximum of viscosity is present at the lowest temperature, and that, as the temperature rises, the maximum becomes less and less pronounced. The determinations were not made at temperatures above  $60^{\circ}$ , but even at this temperature the maximum has in most cases nearly disappeared. But it is known that at  $60^{\circ}$  the association of the molecules of water and the lower alcohols is still not inconsiderable, so that it is perhaps permissible to assume that at higher temperatures the maximum of viscosity may disappear entirely.

The curves also show that the position of the maximum with respect to the axis of abscissas varies in a regular way, so that it is not allowable to conclude that there is any definite relation between the maximum of viscosity and chemical composition, that is, the interpretation of these data in favor of the hypothesis that the maximum marks the existence of a "hydrate" is untrustworthy.

Now, the only data we possess on the internal friction of mixtures of normal liquids are to be found in Wijkander's paper (*loc. cit.*) and these are not very numerous or accessible. The object of this paper is the determination of this physical constant for a number of mixtures of normal liquids.

## II. *Method of Determination of Viscosity.*

The apparatus used in the determinations of the internal frictions of the liquids and their mixtures was that devised by Ostwald.\* Two such instruments were used, one emptying itself of pure water at  $25^{\circ}\cdot 0$  in 105.6 seconds, the other in 203.5 seconds. One or the other was taken so as to make the time of transpiration at least more than 100 seconds. The time was taken by means of a chronometer to within a few tenths of a second. Never less than three and generally from five to ten determinations were made for each mixture, and their average set down as the true time of transpiration. The apparatus was kept in all determinations at the temperature of  $25^{\circ}\cdot 0$  by immersing it in several quarts of water of that temperature contained in a large jar of clear glass. As the coefficient of internal friction varies considerably with the temperature, great care was taken to keep the temperature uniform, and it is believed that during an experiment it did not vary more than  $\pm 0^{\circ}\cdot 02$ . The thermometer used was graduated in tenths of degrees and permitted the estimation of a fiftieth of

\* *Lehrbuch der allgemeinen Chemie*, i, 550, 1889.

a degree; it had been shortly before tested by the "Physikalische Reichsanstalt," and had been found to be without appreciable error in the neighborhood of  $25^{\circ}0$ .

In order to convert the relative coefficients of viscosity, obtained directly from the experimental data furnished by the apparatus, into coefficients of viscosity expressed in dynes per square centimeter, the former were multiplied by the factor 0.00895; this number being the average of the results obtained for water at  $25^{\circ}0$  by Poiseuille, Sprung, Slatte, and Thorpe and Rodger.\*

### III. *Experimental Results.*

In the following tables are recorded the experimental results obtained. In the first two columns are given the percentage composition, in the second two the molecular percentage composition, of the mixtures of liquids investigated. These mixtures were prepared by weighing out to less than a milligram the liquids in tared flasks or bottles fitted with the best corks. The fifth column contains the specific gravities at  $25^{\circ}0$  referred to water at the same temperature. In the sixth column are placed the viscosities of the mixtures as calculated from those of their component liquids by the rule of mixtures, while in the seventh are set the viscosities as actually determined. The eighth column finally shows the differences between the calculated and observed viscosities; a plus sign indicates that the calculated viscosity is greater than that determined; a minus sign, the contrary.

TABLE I.  
*Viscosity of Mixtures of Benzene (a. II) and Ethyl Ether (b.)*  
Temperature  $-25^{\circ}0$

| Percentage composition. |              | Molecular percentage composition. |              | Specific gravity. | Calculated viscosity. | Observed viscosity. | Diff.    |
|-------------------------|--------------|-----------------------------------|--------------|-------------------|-----------------------|---------------------|----------|
| $C_6H_6$                | $C_4H_{10}O$ | $C_6H_6$                          | $C_4H_{10}O$ |                   |                       |                     |          |
| 0.000                   | 100.000      | 0.000                             | 100.000      | 0.70942           |                       | 0.00230             |          |
| 28.576                  | 71.424       | 27.502                            | 72.498       | 0.75369           | 0.00335               | 0.00282             | +0.00052 |
| 56.924                  | 43.076       | 55.627                            | 44.373       | 0.79972           | 0.00440               | 0.00362             | +0.00078 |
| 75.691                  | 24.309       | 74.709                            | 25.291       | 0.83179           | 0.00509               | 0.00438             | +0.00071 |
| 100.000                 | 0.000        | 100.000                           | 0.000        | 0.83390           |                       | 0.00599             |          |

(a. II.) About five pounds of "chemically pure" benzene were treated repeatedly with sulphuric acid to remove last traces of thiophene, and fractionally crystallized many times. It was then distilled over some scraps of sodium, the whole of it boiling at  $80^{\circ}12$  (corr.) under a pressure of  $757.3^{\text{mm}}$  of mer-

\* See Thorpe and Rodger "On the Relations between the Viscosity (Internal Friction) of Liquids and Their Chemical Nature" (Bakerian Lecture), Phil. Trans., 449, 1894.

cury. The distillate was collected in three portions of somewhat over a pound each, and their melting points found to be  $5^{\circ}\cdot39$  (corr.),  $5^{\circ}\cdot40$  (corr.), and  $5^{\circ}\cdot42$  (corr.) respectively.

(b.) Five pounds of ether were washed about twenty times with small portions of water, dried over fused calcium chloride, allowed to stand over mercury for a few days, and finally distilled over sodium. Almost the total quantity distilled within  $0^{\circ}\cdot1$ . The portion which had boiled almost constant was again distilled, this time over phosphoric anhydride, and the distillate collected in two portions, whose specific gravities at  $25^{\circ}\cdot0$  referred to water of the same temperature were found to be  $0\cdot70940$  and  $0\cdot70942$  respectively.

TABLE II.

*Viscosity of Mixtures of Benzene (a. I.) and Toluene (c. I.)*

Temperature  $-25^{\circ}\cdot0$

| Percentage composition. |          | Molecular percentage composition. |          | Specific gravity. | Calculated viscosity. | Observed viscosity. | Diff.    |
|-------------------------|----------|-----------------------------------|----------|-------------------|-----------------------|---------------------|----------|
| $C_6H_6$                | $C_7H_8$ | $C_6H_6$                          | $C_7H_8$ |                   |                       |                     |          |
| 0·000                   | 100·000  | 0·000                             | 100·000  | 0·86288           |                       | 0·00541             |          |
| 10·991                  | 89·009   | 12·719                            | 87·281   | 0·86434           | 0·00547               | 0·00555             | -0·00008 |
| 30·588                  | 69·412   | 34·229                            | 65·771   | 0·86635           | 0·00558               | 0·00558             | 0·00000  |
| 66·576                  | 33·424   | 70·240                            | 29·760   | 0·87143           | 0·00579               | 0·00579             | 0·00000  |
| 91·556                  | 8·444    | 92·750                            | 7·250    | 0·87528           | 0·00594               | 0·00594             | 0·00000  |
| 100·000                 | 0·000    | 100·000                           | 0·000    | 0·87661           |                       | 0·00599             |          |

(a. I.) About three pounds of benzene were treated with sulphuric acid, and then subjected to fractional crystallization until a little more than a pound was obtained melting at  $5^{\circ}\cdot3$  (uncorr.). Most of this, when distilled over sodium, boiled at  $80^{\circ}\cdot1$  (uncorr.) under a pressure of  $756^{\text{mm}}$  of mercury.

(c. I.) Of the quantity of toluene taken for purification (about two pounds) more than four-fifths distilled at  $109^{\circ}\cdot8$  to  $110^{\circ}\cdot1$  (uncorr.). After a couple of distillations over a little sodium, more than a pound was obtained boiling almost constantly at  $110^{\circ}\cdot1$  (uncorr.) under a pressure of  $758^{\text{mm}}$  of mercury.

TABLE III.

*Viscosity of Mixtures of Benzene (a. I.) and Carbon Bisulphide (d.).*

Temperature  $-25^{\circ}\cdot0$

| Percentage composition. |         | Molecular percentage composition. |         | Specific gravity. | Calculated viscosity. | Observed viscosity. | Diff.    |
|-------------------------|---------|-----------------------------------|---------|-------------------|-----------------------|---------------------|----------|
| $C_6H_6$                | $CS_2$  | $C_6H_6$                          | $CS_2$  |                   |                       |                     |          |
| 0·000                   | 100·000 | 0·000                             | 100·000 | 1·25958           |                       | 0·00358             |          |
| 8·872                   | 91·127  | 8·675                             | 91·325  | 1·20897           | 0·00379               | 0·00376             | +0·00003 |
| 34·858                  | 65·142  | 34·270                            | 65·730  | 1·09314           | 0·00456               | 0·00446             | +0·00010 |
| 75·886                  | 24·114  | 75·409                            | 24·591  | 0·94176           | 0·00541               | 0·00544             | -0·00003 |
| 100·000                 | 0·000   | 100·000                           | 0·000   | 0·87661           |                       | 0·00599             |          |



(*d.*) The carbon bisulphide was purified by distillation over dehydrated copper sulphate and mercury, when it was found to have a constant boiling point.

TABLE IV.

*Viscosity of Mixtures of Benzene(a. I.) and Carbon Tetrachloride(e).*  
Temperature 25°0

| Percentage composition.       |                  | Molecular percentage composition. |                  | Specific gravity. | Calculated viscosity. | Observed viscosity. | Diff.     |
|-------------------------------|------------------|-----------------------------------|------------------|-------------------|-----------------------|---------------------|-----------|
| C <sub>6</sub> H <sub>6</sub> | CCl <sub>4</sub> | C <sub>6</sub> H <sub>6</sub>     | CCl <sub>4</sub> |                   |                       |                     |           |
| 0.000                         | 100.000          | 0.000                             | 100.000          | 1.58828           |                       | 0.00883             |           |
| 13.727                        | 86.273           | 23.860                            | 76.140           | 1.42900           | 0.00843               | 0.00808             | + 0.00035 |
| 40.780                        | 59.220           | 57.551                            | 42.449           | 1.19309           | 0.00766               | 0.00706             | + 0.00060 |
| 58.600                        | 41.400           | 73.605                            | 26.395           | 1.07615           | 0.00715               | 0.00660             | + 0.00055 |
| 100.000                       | 0.000            | 100.000                           | 0.000            | 0.87661           |                       | 0.00599             |           |

(*e.*) The carbon tetrachloride had been fractionally distilled over phosphoric anhydride after first being treated with strong sulphuric acid; it boiled at 76°·7 (uncorr.) under a pressure of 754<sup>mm</sup> of mercury.

TABLE V.

*Viscosity of Mixtures of Benzene(a. I.) and Acetic Ether(f. I.)*  
Temperature -25°0

| Percentage composition.       |  | Molecular percentage composition. |  | Specific gravity. | Calculated viscosity. | Observed viscosity. | Diff.     |
|-------------------------------|--|-----------------------------------|--|-------------------|-----------------------|---------------------|-----------|
| C <sub>6</sub> H <sub>6</sub> | C <sub>4</sub> H <sub>8</sub> O <sub>2</sub> | C <sub>6</sub> H <sub>6</sub>     | C <sub>4</sub> H <sub>8</sub> O <sub>2</sub> |                   |                       |                     |           |
| 0.000                         | 100.000                                      | 0.000                             | 100.000                                      | 0.89663           |                       | 0.00434             |           |
| 15.594                        | 84.406                                       | 17.250                            | 82.750                                       | 0.89311           | 0.00459               | 0.00442             | + 0.00017 |
| 51.404                        | 48.596                                       | 54.411                            | 45.589                                       | 0.85506           | 0.00519               | 0.00487             | + 0.00032 |
| 80.803                        | 19.197                                       | 82.605                            | 17.395                                       | 0.87982           | 0.00567               | 0.00551             | + 0.00016 |
| 100.000                       | 0.000  | 100.000                           | 0.000  | 0.87661           |                       | 0.00599             |           |

(*f. I.*) A kilogram of *c. p.* ethyl acetate was fractionally distilled until about a third of it was found to boil within a few tenths of a degree.

TABLE VI.

*Viscosity of Mixtures of Benzene(a. I.) and Nitrobenzene(g).*  
Temperature -25°0

| Percentage composition.       |   | Molecular percentage composition. |   | Specific gravity. | Calculated attrition. | Observed attrition. | Diff.     |
|-------------------------------|---|-----------------------------------|---|-------------------|-----------------------|---------------------|-----------|
| C <sub>6</sub> H <sub>6</sub> | C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub> | C <sub>6</sub> H <sub>6</sub>     | C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub> |                   |                       |                     |           |
| 0.000                         | 100.000                                       | 0.000                             | 100.000                                       | 1.20200           |                       | 0.01834             |           |
| 14.394                        | 85.606  | 20.956                            | 79.044  | 1.14200           | 0.01656               | 0.01417             | + 0.00239 |
| 37.610                        | 62.390  | 48.735                            | 51.265  | 1.05620           | 0.01369               | 0.01017             | + 0.00372 |
| 80.653                        | 19.347  | 86.355                            | 13.645  | 0.92764           | 0.00845               | 0.00681             | + 0.00164 |
| 100.000                       | 0.000   | 100.000                           | 0.000   | 0.87661           |                       | 0.00599             |           |

(*g.*) Commercial nitrobenzene was repeatedly crystallized in fractions until an almost colorless product was obtained, which, when solidified, showed the same temperature during the remelting, viz: 3°·6 (uncorr.)

TABLE VII.

Viscosity of Mixtures of Benzene (a. I.) and Chloroform (h).  
Temperature  $-25^{\circ}0$

| Percentage composition.       |                   | Molecular percentage composition. |                   | Specific gravity. | Calculated viscosity. | Observed viscosity. | Diff.    |
|-------------------------------|-------------------|-----------------------------------|-------------------|-------------------|-----------------------|---------------------|----------|
| C <sub>6</sub> H <sub>6</sub> | CHCl <sub>3</sub> | C <sub>6</sub> H <sub>6</sub>     | CHCl <sub>3</sub> |                   |                       |                     |          |
| 0.000                         | 100.000           | 0.000                             | 100.000           | 1.48069           |                       | 0.00540             |          |
| 6.967                         | 93.033            | 10.290                            | 89.710            | 1.41165           | 0.00544               | 0.00546             | -0.00002 |
| 23.010                        | 76.990            | 31.411                            | 68.589            | 1.27568           | 0.00554               | 0.00557             | -0.00003 |
| 72.780                        | 27.220            | 80.370                            | 19.630            | 0.98485           | 0.00582               | 0.00581             | +0.00001 |
| 85.831                        | 14.169            | 90.289                            | 9.711             | 0.92965           | 0.00590               | 0.00587             | +0.00003 |
| 100.000                       | 0.000             | 100.000                           | 0.000             | 0.87661           |                       | 0.00599             |          |

(h.) The chloroform had been fractionated to constant boiling point, and was finally distilled over phosphoric anhydride; its boiling point was  $61^{\circ}3$  (uncorr.) under a pressure of  $759^{\text{mm}}$  of mercury.

TABLE VIII.

Viscosity of Mixtures of Toluene (c. II.) and Acetic Ether (f. II).  
Temperature  $-25^{\circ}0$

| Percentage composition.       |  | Molecular percentage composition. |  | Specific gravity. | Calculated viscosity. | Observed viscosity. | Diff.    |
|-------------------------------|--|-----------------------------------|--|-------------------|-----------------------|---------------------|----------|
| C <sub>7</sub> H <sub>8</sub> | C <sub>4</sub> H <sub>8</sub> O <sub>2</sub> | C <sub>7</sub> H <sub>8</sub>     | C <sub>4</sub> H <sub>8</sub> O <sub>2</sub> |                   |                       |                     |          |
| 0.000                         | 100.000                                      | 0.000                             | 100.000                                      | 0.89156           |                       | 0.00462             |          |
| 15.708                        | 84.292                                       | 15.129                            | 84.871                                       | 0.88588           | 0.00474               | 0.00466             | +0.00008 |
| 45.301                        | 54.699                                       | 44.202                            | 55.798                                       | 0.87529           | 0.00497               | 0.00481             | +0.00016 |
| 71.255                        | 28.745                                       | 70.335                            | 29.665                                       | 0.86636           | 0.00517               | 0.00509             | +0.00008 |
| 100.000                       | 0.000  | 100.000                           | 0.000  | 0.85680           |                       | 0.00539             |          |

TABLE IX.

Viscosity of Mixtures of Toluene (c. II.) and Ethyl Benzoate (i. I.).  
Temperature  $-25^{\circ}0$

| Percentage composition.       |   | Molecular percentage composition. |   | Specific gravity. | Calculated viscosity. | Observed viscosity. | Diff.    |
|-------------------------------|---|-----------------------------------|---|-------------------|-----------------------|---------------------|----------|
| C <sub>7</sub> H <sub>8</sub> | C <sub>9</sub> H <sub>10</sub> O <sub>2</sub> | C <sub>7</sub> H <sub>8</sub>     | C <sub>9</sub> H <sub>10</sub> O <sub>2</sub> |                   |                       |                     |          |
| 0.000                         | 100.000                                       | 0.000                             | 100.000                                       | 1.04843           |                       | 0.01954             |          |
| 15.282                        | 84.718  | 22.726                            | 77.274  | 1.01458           | 0.01737               | 0.01495             | +0.00242 |
| 47.322                        | 52.678  | 59.450                            | 40.550  | 0.94937           | 0.01284               | 0.00939             | +0.00345 |
| 76.170                        | 23.830  | 83.918                            | 16.082  | 0.89667           | 0.00876               | 0.00679             | +0.00197 |
| 100.000                       | 0.000   | 100.000                           | 0.000   | 0.85680           |                       | 0.00539             |          |

(i.) Ethyl benzoate was prepared by the action of hydrochloric acid on a mixture of benzoic acid and absolute alcohol. It was repeatedly rectified, and the fraction boiling at  $210^{\circ}3$ – $210^{\circ}8$  employed in the determinations.

TABLE X.  
*Viscosity of Mixtures of Toluene (c. I) and Carbon Bisulphide (d).*  
Temperature  $-25^{\circ}\text{C}$

| Percentage composition. |               | Molecular percentage composition. |               | Specific gravity. | Calculated viscosity. | Observed viscosity. | Diff.    |
|-------------------------|---------------|-----------------------------------|---------------|-------------------|-----------------------|---------------------|----------|
| $\text{C}_7\text{H}_8$  | $\text{CS}_2$ | $\text{C}_7\text{H}_8$            | $\text{CS}_2$ |                   |                       |                     |          |
| 0.000                   | 100.000       | 0.000                             | 100.000       | 1.25958           |                       | 0.00358             |          |
| 7.269                   | 92.731        | 6.082                             | 93.918        | 1.21783           | 0.00377               | 0.00370             | +0.00007 |
| 39.992                  | 62.008        | 33.605                            | 66.395        | 1.06759           | 0.00427               | 0.00417             | +0.00010 |
| 63.242                  | 36.758        | 58.699                            | 41.301        | 0.97217           | 0.00473               | 0.00469             |          |
| 100.000                 | 0.000         | 100.000                           | 0.000         | 0.86288           |                       | 0.00541             |          |

TABLE XI.  
*Viscosity of Mixtures of Toluene (c. II) and Turpentine (k).*  
Temperature  $-25^{\circ}\text{C}$

| Percentage composition. |                              | Molecular percentage composition. |                              | Specific gravity. | Calculated viscosity. | Observed viscosity. | Diff.    |
|-------------------------|------------------------------|-----------------------------------|------------------------------|-------------------|-----------------------|---------------------|----------|
| $\text{C}_7\text{H}_8$  | $\text{C}_{10}\text{H}_{16}$ | $\text{C}_7\text{H}_8$            | $\text{C}_{10}\text{H}_{16}$ |                   |                       |                     |          |
| 0.000                   | 100.000                      | 0.000                             | 100.000                      | 0.85970           |                       | 0.01343             |          |
| 6.791                   | 93.209                       | 9.724                             | 90.276                       | 0.85948           | 0.01275               | 0.01192             | +0.00083 |
| 20.654                  | 79.346                       | 27.464                            | 72.536                       | 0.85838           | 0.01177               | 0.00978             | +0.00199 |
| 53.701                  | 46.299                       | 63.162                            | 36.838                       | 0.85682           | 0.00911               | 0.00701             | +0.00200 |
| 75.091                  | 24.909                       | 89.884                            | 20.116                       | 0.85654           | 0.00739               | 0.00607             | +0.00131 |
| 100.000                 | 0.000                        | 100.000                           | 0.000                        | 0.85680           |                       | 0.00539             |          |

(*k*.) The sample of turpentine used was kindly furnished me by Prof. J. H. Long of the North Western University, who had had it prepared in his laboratory from pure spruce gum. It had been rectified over sodium and boiled at  $156^{\circ}\text{--}157^{\circ}\text{C}$  (uncorr.) under a pressure of  $745^{\text{mm}}$  of mercury.

TABLE XII.  
*Viscosity of Mixtures of Ether (m. b) and Carbon Bisulphide (d).*  
Temperature  $-25^{\circ}\text{C}$

| Percentage composition.           |               | Molecular percentage composition. |               | Specific gravity. | Calculated viscosity. | Observed viscosity. | Diff.    |
|-----------------------------------|---------------|-----------------------------------|---------------|-------------------|-----------------------|---------------------|----------|
| $\text{C}_4\text{H}_{10}\text{O}$ | $\text{CS}_2$ | $\text{C}_4\text{H}_{10}\text{O}$ | $\text{CS}_2$ |                   |                       |                     |          |
| 0.000                             | 100.000       | 0.000                             | 100.000       | 1.25958           |                       | 0.00358             |          |
| 13.100                            | 86.900        | 13.407                            | 86.593        | 1.14280           | 0.00341               | 0.00338             | +0.00003 |
| 34.367                            | 65.633        | 34.969                            | 65.031        | 0.99180           | 0.00313               | 0.00306             | +0.00007 |
| 62.759                            | 37.241        | 63.380                            | 36.620        | 0.81689           | 0.00277               | 0.00269             | +0.00008 |
| 100.000                           | 0.000         | 100.000                           | 0.000         | 0.70942           |                       | 0.00230             |          |

TABLE XIII.  
*Viscosity of Mixtures of Acetic Ether (f. II) and Ethyl Iodide (n).*  
Temperature  $-25^{\circ}\text{C}$

| Percentage composition.          |                                | Molecular percentage composition. |                                | Specific gravity. | Calculated viscosity. | Observed viscosity. | Diff.    |
|----------------------------------|--------------------------------|-----------------------------------|--------------------------------|-------------------|-----------------------|---------------------|----------|
| $\text{C}_4\text{H}_8\text{O}_2$ | $\text{C}_2\text{H}_5\text{I}$ | $\text{C}_4\text{H}_8\text{O}_2$  | $\text{C}_2\text{H}_5\text{I}$ |                   |                       |                     |          |
| 0.000                            | 100.000                        | 0.000                             | 100.000                        | 1.93015           |                       | 0.00577             |          |
| 21.799                           | 78.201                         | 33.073                            | 66.927                         | 1.52760           | 0.00552               | 0.00408             | +0.00144 |
| 67.427                           | 32.573                         | 78.585                            | 21.415                         | 1.07553           | 0.00499               | 0.00462             | +0.00037 |
| 100.000                          | 0.000                          | 100.000                           | 0.000                          | 0.89156           |                       | 0.00462             |          |



*n.* The ethyl iodide was made by the action of iodine and red phosphorus on absolute alcohol; by a couple of distillations, a constant boiling product was obtained, which when again distilled gave two fractions having specific gravities at 25°0 referred to water at the same temperature, 1·93012 and 1·93015 respectively.

TABLE XIV.

*Viscosity of Mixtures of Acetic Ether (f.I) and Nitrobenzene (g).  
Temperature -25°0*

| Percentage composition.                       |  | Molecular percentage composition.             |  | Specific gravity. | Calculated viscosity. | Observed viscosity. | Diff.    |
|---|--|---|--|-------------------|-----------------------|---------------------|----------|
| C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub> | C <sub>4</sub> H <sub>8</sub> O <sub>2</sub> | C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub> | C <sub>4</sub> H <sub>8</sub> O <sub>2</sub> |                   |                       |                     |          |
| 0·000   | 100·000                                      | 0·000   | 100·000                                      | 0·89663           |                       | 0·00434             |          |
| 22·896  | 77·104                                       | 17·530  | 82·470                                       | 0·95669           | 0·00755               | 0·00582             | +0·00173 |
| 56·100  | 43·900                                       | 47·770  | 52·230                                       | 1·05318           | 0·01219               | 0·00889             | +0·00350 |
| 75·530  | 24·470                                       | 68·870  | 31·130                                       | 1·11618           | 0·01491               | 0·01204             | +0·00287 |
| 100·000                                       | 0·000  | 100·000                                       | 0·000  | 1·20200           |                       | 0·01834             |          |

TABLE XV.

*Viscosity of Mixtures of Carbon Tetrachloride (e) and Chloroform (h).  
Temperature -25°0*

| Percentage composition. |                   | Molecular percentage composition. |                   | Specific gravity. | Calculated viscosity. | Observed viscosity. | Diff.    |
|-------------------------|-------------------|-----------------------------------|-------------------|-------------------|-----------------------|---------------------|----------|
| CCl <sub>4</sub>        | CHCl <sub>3</sub> | CCl <sub>4</sub>                  | CHCl <sub>3</sub> |                   |                       |                     |          |
| 0·000                   | 100·000           | 0·000                             | 100·000           | 1·48069           |                       | 0·00540             |          |
| 19·269                  | 80·731            | 15·663                            | 84·337            | 1·49872           | 0·00610               | 0·00569             | +0·00041 |
| 57·277                  | 42·723            | 50·989                            | 49·011            | 1·53772           | 0·00736               | 0·00659             | +0·00077 |
| 81·172                  | 18·828            | 76·985                            | 23·015            | 1·56489           | 0·00818               | 0·00761             | +0·00057 |
| 100·000                 | 0·000             | 100·000                           | 0·000             | 1·58828           |                       | 0·00883             |          |

TABLE XVI.

*Viscosity of Mixtures of Acetic Ether (f. II) and Carbon Bisulphide (d).  
Temperature -25°0*

| Percentage composition.          |                 | Molecular percentage composition. |                 | Specific gravity. | Calculated viscosity. | Observed viscosity. | Diff.    |
|----------------------------------|-----------------|-----------------------------------|-----------------|-------------------|-----------------------|---------------------|----------|
| C <sub>4</sub> H <sub>10</sub> O | CS <sub>2</sub> | C <sub>4</sub> H <sub>10</sub> O  | CS <sub>2</sub> |                   |                       |                     |          |
| 0·000                            | 100·000         | 0·000                             | 100·000         | 1·25958           |                       | 0·00358             |          |
| 16·359                           | 83·641          | 14·451                            | 85·549          | 1·16956           | 0·00375               | 0·00367             | +0·00008 |
| 39·246                           | 60·754          | 35·811                            | 64·189          | 1·06877           | 0·00398               | 0·00389             | +0·00009 |
| 66·413                           | 33·587          | 63·069                            | 36·931          | 0·97681           | 0·00427               | 0·00416             | +0·00011 |
| 100·000                          | 0·000           | 100·000                           | 0·000           | 0·89156           |                       | 0·00462             |          |

(*c. II.*) Five pounds of toluene were fractionally distilled over sodium a half dozen times or so until the larger portion boiled almost at a constant temperature. Three fractions of nearly a pound each were then made, boiling: *a* at 109°·90–109°·94; *b* at 109°·94–110°·00; and *c* at 110°·00–110°·03 under a pressure of 757·7<sup>mm</sup> of mercury. Their specific gravities at 25°0 referred to water at 25°0 were: *a*, 0·85678; *b*, 0·85681 and *c*, 0·85680.

(*f. II.*) Five pounds of commercial acetic ether were dried over fused calcium chloride for a few days; and after filtration from this salt were made to stand over phosphoric anhydride for some time. The ether was then distilled, the distillate being collected in two portions, one of which boiled at  $71^{\circ}0-71^{\circ}3$  (uncorr.), the other at  $71^{\circ}3-71^{\circ}4$  (uncorr.) Each of these distillates was again distilled over phosphoric anhydride, and both were found to boil at identical temperatures. The specific gravity of one sample at  $25^{\circ}0$  referred to water at the same temperature was determined to be 0.89155; that of the other under similar conditions, 0.89157.

#### IV. *Discussion of Results.*

The data in the preceding section are seen to be in corroboration of Wijkander's (*loc. cit.*) results; in no instance does a maximum of viscosity appear. The observed viscosities are all less than those calculated by the rule of mixtures, except in certain mixtures of benzene and chloroform (Table VII) and of benzene and carbon bisulphide (Table III); in these mixtures, however, the differences are less than those detectible by the apparatus, so that they cannot be really counted as exceptional.

With mixtures of certain liquids, as of benzene and toluene (Table II), benzene and carbon bisulphide (Table III), benzene and chloroform (Table VII), toluene and carbon bisulphide (Table X, ether and carbon bisulphide (Table XII) and acetic ether and carbon bisulphide (Table XVI) the differences are so slight that they may be due principally to experimental errors, and, consequently, these liquids may be said to preserve their viscosities without appreciable change in mixture. In other mixtures, on the contrary, considerable differences between the theoretical and found values of the viscosities present themselves, the greatest differences occurring when about equal proportions of the liquids are mixed.

The greater the differences between the viscosities of the pure liquids, the greater is found to be the differences between the calculated and observed values of the viscosities of their mixtures. This is easily seen in the mixtures of benzene, whose viscosity is 0.00599, and nitrobenzene, whose viscosity is 0.01834, differences amounting to 0.00372 being found (Table VI); also, in mixtures of toluene (viscosity = 0.01954), where the differences, found and calculated, are as large as 0.00345.

Yet, even when the viscosities of the pure liquids are nearly the same, the differences between the theoretical and observed values of the viscosities of their mixtures is not inconsiderable; thus the mixtures of acetic ether (viscosity = 0.00577) and ethyl iodide (viscosity = 0.00462) there are differences of as much as 0.00144.

ART. XLIX.—*Volume Measurement of an Air Thermometer Bulb*; by WALTER G. CADY.

IN all constant volume air thermometry where high temperatures are involved, it is frequently necessary to determine the volume of the glass bulb used; such a bulb softens at a low red heat sufficiently to have its volume considerably altered by any difference between the atmospheric pressure and that within the bulb. Thus it is important to know at the end of an experiment to what extent, if any, the volume of the bulb may have changed, as any such change must be taken into account in calculating the temperature.

The usual method of volumetry by weighing with water is long and arduous, involving as it does the taking apart of the apparatus. Below is given a simple and sufficiently accurate method of calculating the volume at any time without disconnecting the bulb. In addition to the usual apparatus it is only necessary that the manometer tube in which the air is confined be graduated for 9 or 10<sup>cm</sup> from the top, so that the volume of air in the tube may be computed.

In the figure, *B* is the bulb, *PP* a capillary connecting tube, *T* the graduated manometer tube, the graduated portion of which is about 1<sup>cm</sup> in diameter, connected in the customary manner by flexible rubber tubing with a reservoir. The scale in question is shown at *T* and is graduated in 0.1<sup>cms</sup> beginning with the fiducial mark.

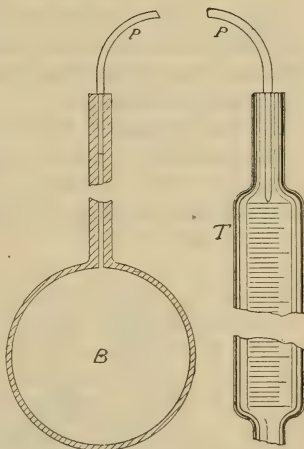
Assuming the whole apparatus to be at constant temperature during the operation, the required volume *V* is easily found as

$$V = \frac{P_2 v_2 - P_1 v_1}{P_1 - P_2}$$

when *v*<sub>2</sub> and *v*<sub>1</sub> are volume excesses measured by means of the scale on *T*, corresponding to pressures *P*<sub>2</sub> and *P*<sub>1</sub> respectively.

It will be observed that *V* is not the volume of the bulb alone. Still, since the bulb is the only variable factor, the above formula indicates what change it may undergo.

The following is an example of a number of observations leading to the volume of a glass bulb used; in each case the





first reading is combined with the third, the second with the fourth, in finding the values of  $P_2 v_2 - P_1 v_1$  and  $P_1 - P_2$ .

Reduced atmospheric pressure =  $74.76^{\text{cm}}$ .

| P (cm.) | v (c.c.) | V (c.c.) |
|---------|----------|----------|
| 75.17   | 0.16     | 239.0    |
| 74.63   | 1.80     | 241.1    |
| 73.79   | 4.47     |          |
| 73.27   | 6.20     |          |

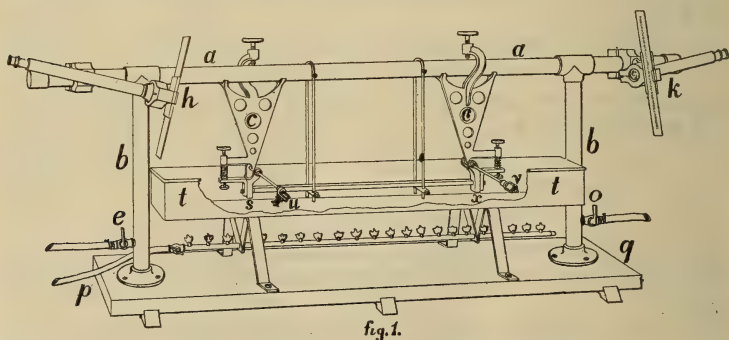
The method is equally serviceable when a long capillary of irregular and appreciable volume joins the bulb with the manometer, a condition sometimes unavoidable in practice: the volume of the capillary may then be separately found by temporarily plugging up its detached end.

Wilson Phys. Lab., Brown University, Providence, R. I.

ART. L.—*The Effect of Residual Viscosity on Thermal Expansion*; by HOWARD D. DAY.

In the course of certain laboratory experiments, I observed a condition of molecular instability in vulcanized rubber, due to residual viscosity, which seems to be of sufficient interest to deserve publication.

As the detection of this quality in rubber was made possible by the excellent performance of the apparatus which I employed, a brief description of it will here be given, use being made of the accompanying figure 1.



The apparatus is essentially the well known German apparatus for noting the expansion of solids through ranges of temperature, but it will be seen to embody several novel features,

which, while they are attained by comparatively simple means, yet add greatly to the value of the results obtained by its use; notably, the way in which a base of constant length for a reasonable length of time is secured, and, also, the construction of the parts which support the movable levers, so as to accommodate the use of the apparatus to bars of any length.

A bar of the solid substance whose expansion is to be observed is submerged in the bath, *tt*, which is supported by standards above a solid wooden base, *pg*. The temperature of the bath is raised by means of a multiple gas-jet suspended beneath it.

The ends of the bar actuate contact levers of a convenient pattern, *s* and *x*, which are free to move about horizontal axes. Two rods, projecting from these levers in the line of their axes, support the adjustable mirrors, *u* and *v*. The angular motion of the levers, which measures the expansion of the bar, is determined in the usual way by means of these mirrors and the two telescopes, *h* and *k*, with their attached scales. Any lost motion of the levers is prevented by spiral springs, which, having their ends attached respectively to the fixed parts of the apparatus supporting the levers and to arms on the levers themselves, keep them pressed firmly against the ends of the bar. Thumb-screws serve to regulate the tension of the springs.

In observing expansions, the work is much facilitated, if, instead of having both levers movable, one lever, with its mirror, is maintained in a fixed position by its spring, while all of the motion is exhibited by the other. In this case, the fixity of the non-movable mirror is assured by means of its corresponding telescope.\*

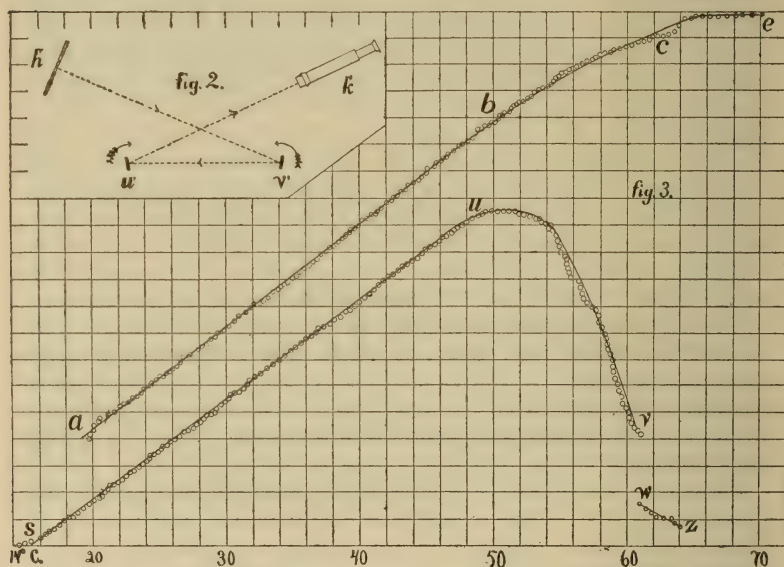
Another arrangement of the optical parts of the apparatus is shown in fig. 2. The telescope *h* is removed and a scale, *h'*, fixed in its place. Both of the mirrors have a possible rotation in the direction of the arrows. The reflected scale image reaches the eye at the telescope, *k'*, over the path indicated by the dotted lines and arrow heads. Since the successive deflections of the scale-image by the two mirrors are of the same sign, the deflection observed at the telescope will correctly measure the sum of all possible motions of the levers due to either expansion or contraction of the bar. It is clear that the lengths of the contact levers will have to be proportional to the corresponding scale distances, that of the stationary mirror, *u'*, being the longer.

A base of constant length is secured by the following simple means: A bar of  $1\frac{1}{2}$ " galvanized iron pipe, *aa*, is supported in a horizontal position directly above the bath upon uprights, *bb*,

\* I am aware that similar observations with two telescopes were made on a certain occasion by Prof. W. Hallock.

of the same material, which are connected with it by "T" joints at a short distance from its ends.

These uprights are screwed into circular cast-iron plates, which are rigidly fastened to the wooden base, *pq*. Stop-cocks are inserted in the sides of the uprights near their lower ends, at *e* and *o*. By means of caps on the projecting ends of the bar, *aa*, and plugs in the lower ends of the uprights, *bb*, the framework of piping is made water-tight, and, by connecting one of the cocks, *e*, *o*, with a source and the other with a sink, a continuous flow of water throughout the length of the bar, *aa*, is obtained.



If the temperature of the water passing through the bar remains constant, the bar will not be sensibly affected by the currents of heated air rising from the jets beneath the bath, and the length of any portion of the bar will remain constant. A public main is a convenient source, and, for a reasonable time, will supply a flow of water at a nearly constant temperature.

The projecting ends of the bar, *aa*, serve as convenient supports for the telescopes, *h* and *k*, which are fastened thereto in an adjustable manner, so as to allow them to be focussed upon their respective mirrors, *v* and *u*.

The solid whose expansion is to be observed is suspended in the bath from the bar, *aa*, by light bent rods, while the levers, *s*, *x*, are supported below the same bar, in their proper positions at the ends of the solid, by brackets, *e*, *e*, cast in brass. These



brackets may be clamped in any position along the bar, *aa*, by means of thumb-screws and projecting jaws, and their form is such that they successfully resist the slight force tending to separate their lower extremities.

Since the portion of the bar *aa*, between the brackets is constant in length, owing to the stream of water passing through, it is readily seen that a base of constant length is provided, and that, too, in a simple and effective manner.

Moreover, by means of the movable brackets, the apparatus may be accommodated to solids varying widely in their coefficients of expansion. Thus, the apparatus permitted the testing of a standard meter rod for temperature corrections, while, in the experiments with hard rubber, which are referred to above, a piece of this substance but 15<sup>cm</sup> in length, which was sufficient to give conveniently large scale-deflections, was used, and the apparatus was readily adjusted to this length of rod.

The data obtained with metal rods are of no special interest, except as they point out the degree of accuracy of the results obtained with the apparatus; at the same time the action of the apparatus is well enough shown in the results obtained with the hard rubber rod, which are exhibited as expansion curves in the accompanying diagram, fig. 3.

A piece of hard rubber tube was examined by means of this apparatus, to determine the range of temperature through which it would maintain a uniform rate of expansion, with results as shown by the curve, *suw-wz*. The rubber maintained a nearly uniform rate up to 50°, when an apparent rapid contraction took place until 61° was reached. At this point the bath was allowed to cool off several degrees and then was raised to 64°, giving the short, detached portion of the curve, *wz*. Evidently, the apparent contraction went on during the cooling and reheating of the bath below 61°. This fact gives a clue to the real cause of the apparent contraction; that it was no real contraction due to a rise in temperature, such as is shown by rubber under certain well-known conditions, but a viscous readjustment of the molecules, after being released by the heat of the bath from a condition of stress due to the previous treatment of the rubber,—probably, in its manufacture.

A subsequent test of the same piece of rubber gave further evidence of this condition of residual viscosity, as is shown by the curve, *abce*. The rubber, as before, maintained a uniform rate up to 50°. From this point up to 64°, a gradual diminution of the rate is observed. At 64°, the highest temperature to which the rubber was previously subjected, a rapid decline is noted.

These results clearly show that the rubber is molecularly stable at a given temperature, if it has long been exposed to

that temperature. When this temperature is reached the residual viscosity again manifests itself, and the rubber undergoes further gradual deformation, which vanishes in its turn.

Thus, the hard rubber tube was evidently stretched at the relatively high temperature of manufacture. The stress was locked up in the tube and maintained at ordinary temperatures. Between  $50^{\circ}$  and  $64^{\circ}$ , however, this was not so, and a viscous flow took place, resulting in a shortening of the tube, as shown by the diagram.

The second measurement of the expansion shows that, during the previous exposure to the temperature  $50^{\circ} \dots 64^{\circ}$ , excess of strain was nearly wiped out. When the temperature  $64^{\circ}$  was again reached, however, the viscous yielding reappeared.

Phenomena in tempered steel analogous to this in rubber have been observed in great detail by Barus and Strouhal,\* and they have made use of their observations in the production of steel magnets of remarkably stable qualities. They found that steel possessed residual viscosity, which manifested itself as an irregular change of the magnetization in permanent magnets when exposed to relatively high temperatures. By boiling their magnets in water for many hours, they found that they could remove such residual viscosity and render them viscously stable below  $100^{\circ}$ . This treatment is applied successively both to remove excess of mechanical strain and of magnetization.

A practical result of a knowledge of this quality would be to secure rubber of a stable molecular condition by subjecting it to a heating process; e. g, by boiling it in water for a considerable length of time.

Although the viscous motion in metals is much smaller, it would, nevertheless, seem advisable to submit rods intended as *standards of length* to a thorough boiling in water prior to their final calibration, particularly when the metal is drawn or rolled.

Wilson Physical Laboratory,  
Brown University, Providence, R. I.

\* Bulletin No. 73, 1891, U. S. Geological Survey.

ART. LI.—*On the Induction Coefficients of Hard Steel Magnets*; by B. O. PEIRCE.

IN preparing a large number of deflecting magnets for the use of students in measuring by Gauss's method the intensity,  $H$ , of the horizontal component of the earth's magnetic field, I have had occasion to make several hundred measurements of the induction coefficients of seasoned magnets of different sizes and shapes. The results of this work have enabled me to predict with considerable accuracy what measurement would show the induction coefficients of various other magnets to be, and, since an approximate knowledge of the induction coefficient of a magnet is sufficient for many practical purposes, I hope that these results may prove useful to others.

A short account of the way in which the deflecting magnets were made will serve to show the scope of the observations and to explain some terms used in the sequel.

The fact that a great many sets of apparatus were required, each capable of giving accurate results, determined in some degree the character of this apparatus. It was desirable that no two of the deflecting magnets should be just alike, but it was essential that every one of them should be homogeneous and of such a form that its moment of inertia could be computed with an error less than  $\frac{1}{5}$  per cent, corresponding to an error from this cause of  $\frac{1}{10}$  per cent in a determination of  $H$ .

Notwithstanding their advantages, extremely slender magnets hardened in bundles like those which led to excellent results in the hands of Professor T. Gray,\* were for several reasons unsuited to my purpose; accurately made hollow magnets would have been expensive, and it seemed best to use solid round rod magnets from 0.8<sup>cm</sup> to 0.95<sup>cm</sup> in diameter. Extremely homogeneous, round, polished drill rod of Stubs or Crescent steel was easily obtainable, and, to avoid as far as possible the necessity of grinding the hardened steel to form, the magnets were generally cut from long perfect specimens of this drill rod and the ends of the pieces were ground flat. The steel was then heated uniformly to a bright red by aid of a special gas-heater devised by Mr. G. W. Thompson, the mechanician of the Jefferson Laboratory, and immersed in a large bath of rapidly-stirred, ice-cold, acidulated water. In this way great uniformity was obtained in the hardening. The ends of the hardened pieces were very slightly ground again under water in a special holder on a Brown and Sharpe grinder. This gave a mirror surface at each end accurately perpendicular to the axis of the magnet without disturbing the temper in the

\* A. Gray: *Absolute Measurements in Electricity and Magnetism*, ch. 2.



slightest degree. In most cases it was not necessary to grind the cylindrical surface true.

The hardened steel was either exposed to steam at  $100^{\circ}$  C. or immersed in boiling water for a long time, in order to "relax" the temper in the manner proposed by Messrs. Barus and Strouhal,\* and each piece was then very slightly oiled while still hot. After this treatment the steel would still cut ordinary hard window glass.

The pieces were magnetized between the poles of a soft iron yoke in a long solenoid, having 32 turns of wire per centimeter of its length, by a current of about 25 amperes. By this arrangement it was possible to force through every piece of steel at least 18,000 lines of induction per square centimeter of the cross section.

The magnets were finally "seasoned," according to the directions of Messrs. Barus and Strouhal, by a second long exposure to boiling water or to steam at  $100^{\circ}$  C. Some magnets thus prepared have been repeatedly thrown upon the floor and one received about a hundred smart blows on end from a bar of magnetized steel without any perceptible loss of permanent magnetic moment.

A hundred magnets of the same size made in this way of the same kind of steel would be almost indistinguishable, but the inside of a thick piece of steel is evidently left a little less hard than the outer skin. The rate of change (with the length) of the specific magnetic moment of a very short seasoned magnet of given large cross section, sometimes decreases slightly as the length increases, and, in the case of some comparatively long pieces of thick steel, magnetization, contrary to the general rule,† increases the induction coefficient. It is easy to get various specific moments and great differences in the effective lengths of magnets of the same actual size made of steel wire hardened in a bundle.

Because most of the measurements of induction coefficients which I found recorded‡ were made either with unseasoned magnets or with magnets very different in shape from those which I was to use, I felt compelled not only to determine directly the induction coefficients of all the deflecting magnets but to test a large number of magnets made of other kinds of

\* Bulletin of the U. S. Geological Survey, No. 14, 1885.

† Ewing: Magnetic Induction in Iron and other metals, ch. vi.

Rayleigh: Phil. Mag., 1887.

‡ Kupffer: Pogg. Ann., 1828.

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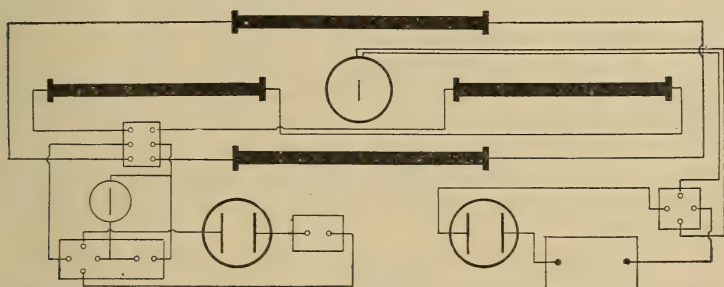
Kohlrausch: Wied. Ann., 1884.

Nachrichten d. k. Gesellschaft d. Wissenschaften, Göttingen, 1883.

H. Sack: Inaugural Diss., Frankfurt, 1886.

steel in order to find out whether any of these were much superior to magnets of similar shape made of drill rod. The determinations were made\* with the aid of an induction bench two meters long furnished with two pairs of solenoids so placed and connected that a steady current passing successively through the coils of either pair would not deflect the magnetometer needle. This needle was closely surrounded by a small coil through which, in experimenting upon a magnet, a steady current could be sent just strong enough to balance the deflecting force of the magnet when placed in the center of any of the solenoids. The general arrangement of the apparatus appears in figure 1. The deflections of the magnetome-

1.



ter needle were measured by means of a telescope and scale; the strength of the weak current sent at any time through the solenoids, by a sensitive voltmeter in multiple arc with a standard resistance in the main circuit. The strength of the earth's magnetic field at the center of the magnetometer was known.

After an unmagnetized specimen of hard steel had been inserted in the center of one of the solenoids, at a known distance from the magnetometer needle, a steady current so weak as not to leave any perceptible permanent magnetism† in the steel was sent through the solenoid. This current was reversed twenty times and then the deflection of the needle was measured for each direction of the current. With the customary correction‡ for the effective length of the steel, it was easy to compute the moment of the induced magnetism so that a similar measurement made in one of the other pair of solenoids would give practically the same result. Sometimes a number of measurements were made with the same specimen, using different magnetizing currents in order to make sure that the

\* Maxwell: Treatise on Electricity and Magnetism, § 457.

Winkelmann: Handbuch der Physik, III, ii, p. 69.

Joule: Proc. Phil. Soc., Manchester, 1867.

† In the cases of some short pieces, a field of 3°ga units was not too strong.

‡ Riecke: Wied. Ann., 1879.

limit had not been passed below which the induced moment was proportional to the strength of the magnetizing field. The induced moment was occasionally measured by balancing the deflecting action of the induced magnetism by means of a known current sent through a second small coil close to the magnetometer needle. The rather complicated apparatus is not shown in the diagram, for the method is not very convenient though it gives excellent results.

A steel bar magnet could be tested in the same manner as an unmagnetized bar, after the defective effect of the permanent magnetism had been balanced by the help of a suitable steady current from the storage cell at the right of the diagram. The permanent magnetic moments of the seasoned magnets were determined on a long magnetometer bench in Gauss's "A position." Observations were made by myself and by Mr. C. G. Persons on several hundred pieces of steel at various stages on their way toward becoming seasoned magnets. The induction coefficients and the magnetic moments, though they were determined with some accuracy, are given only approximately in the subjoined tables, and I believe that most of them fairly represent what a second set of similar magnets would give.

It is proper to say that some of the Crescent drill rod of which I had a large quantity was obtained directly from the Crescent Steel Company of Pittsburg, but that much more was purchased of different dealers at different times. The Stubs and Jessops steels were also bought on various occasions of different dealers, and I venture to hope that my specimens fairly represent these steels. After testing large numbers of magnets made of Crescent polished drill rod and of Jessops round black tool steel I can only say that when hard these steels seem to be magnetically indistinguishable, though abnormal specimens occur. The Jessops steel is cheaper than the other but rougher and, as sold in the market, less thoroughly annealed. A stout magnet made of Stubs polished drill rod generally has a somewhat smaller permanent specific magnetic moment than a similar magnet made of either Crescent drill rod or of Jessops round tool steel, as appears from the results recorded in Tables I and II.

Table II represents observations made on a very large number of magnets. Each number in Table III, on the other hand, is based on measurements of only two specimens, cut from one of 21 sample rods very kindly furnished by the Crescent Steel Company. Table IV records tests made upon four odd magnets.

In order to compare more exactly relatively stout magnets made of Crescent drill rod, Stubs drill rod and Jessops round tool steel, I procured of an instrument maker a large number of hardened pieces of steel of each of these kinds, of



different lengths, but all 0·95<sup>cms</sup> in diameter. It soon appeared that the hardening was not sufficiently uniform to serve my purpose, so I reheated and hardened all these pieces. This process, as was to be expected, injured the steel by increasing the induction coefficients and decreasing the permanent magnetic moments of the seasoned magnets. This appears from measurements given in Table V, in which the first four columns apply to all the pieces, but the last column only to the Jessops and Crescent steels, which were almost exactly alike after the rehardening. The permanent magnetic moments of the Stubs steel magnets were only about half those of corresponding magnets made of the other steels. The results of observations upon numerous pieces of Jessops square and flat tool steel appear in Tables VI and VII.

I have tested a number of magnets made of the "special magnet steels" of different makers. These all had, of course, relatively high permanent moments, but most of these steels are difficult to work and I have not yet been able to procure a sufficient quantity of any one of them, in shape suitable for the making of deflecting magnets, to enable me to compare the advantages of such magnets over those made of fine tool steel.

TABLE I.—*Magnets made of Round Polished Drill Rod.*

| Brand.         | Length in centimeters. | Diameter in centimeters. | Moment per gramme of the magnetism induced in the seasoned magnet when placed lengthwise in a unit field. | Permanent magnetic moment per gramme of the seasoned magnet. | Approximate ratio of the induced magnetic moment to the permanent moment of the magnet. |
|----------------|------------------------|--------------------------|---|--|---|
| Crescent ..... | 12                     | 0·64                     | 0·23  | 27   | 0·009   |
| Stubs .....    | 12                     | 0·64                     | 0·20  | 27   | 0·008   |
| Crescent ..... | 12                     | 0·48                     | 0·21  | 31   | 0·007   |
| Stubs .....    | 12                     | 0·48                     | 0·18  | 30   | 0·006   |
| Crescent ..... | 12                     | 0·30                     | 0·22  | 36   | 0·006   |
| Stubs .....    | 12                     | 0·30                     | 0·18  | 36   | 0·005   |
| Crescent ..... | 10                     | 0·64                     | 0·19  | 25   | 0·008   |
| Stubs .....    | 10                     | 0·64                     | 0·19  | 24   | 0·008   |
| Crescent ..... | 10                     | 0·48                     | 0·19  | 30   | 0·006   |
| Stubs .....    | 10                     | 0·48                     | 0·18  | 27   | 0·007   |
| Crescent ..... | 10                     | 0·30                     | 0·20  | 30   | 0·007   |
| Stubs .....    | 10                     | 0·30                     | 0·18  | 25   | 0·007   |
| Crescent ..... | 8                      | 0·64                     | 0·20  | 20   | 0·010   |
| Stubs .....    | 8                      | 0·64                     | 0·18  | 16   | 0·011   |
| Crescent ..... | 8                      | 0·48                     | 0·19  | 21   | 0·009   |
| Stubs .....    | 8                      | 0·48                     | 0·18  | 19   | 0·009   |
| Stubs .....    | 6                      | 0·80                     | 0·15  | 10   | 0·015   |
| Stubs .....    | 8                      | 0·80                     | 0·18  | 12   | 0·015   |
| Stubs .....    | 10                     | 0·80                     | 0·20  | 14   | 0·014   |
| Stubs .....    | 12                     | 0·80                     | 0·22  | 17   | 0·013   |
| Stubs .....    | 15                     | 0·80                     | 0·24  | 21   | 0·011   |
| Stubs .....    | 18                     | 0·80                     | 0·26  | 28   | 0·009   |
| Stubs .....    | 20                     | 0·80                     | 0·27  | 35   | 0·008   |

TABLE II.—*Polished Crescent Steel Drill Rod.*

| Length in centimeters. | Diameter in centimeters. | Weight in grammes per centimetre of length. | Moment per gramme of magnetism induced in the specimen when placed lengthwise in a unit field. |                                 |   |  | Permanent magnetic moment per gramme of the seasoned magnet. | Approximate ratio of the induced moment caused by unit field to the permanent moment in the seasoned magnet. |
|------------------------|--------------------------|---|--|---------------------------------|---|--|--|--|
|                        |                          |   | In the condition in which it was purchased.  | When "glass-hard" unmagnetized. | When magnetized and saturated in which it was "glass-hard." | In the condition of a seasoned magnet. |  |  |
| 20                     | 1.11                     | 7.6   | 0.44   | 0.23                            | 0.28  | 0.30                                   | 30.5   | 0.010  |
| 18                     |                          |   | 0.41   | 0.22                            | 0.26  | 0.28                                   | 25.5   | 0.011  |
| 16                     |                          |   | 0.38   | 0.21                            | 0.24  | 0.25                                   | 21.5   | 0.012  |
| 14                     |                          |   | 0.34   | 0.20                            | 0.22  | 0.23                                   | 17.5   | 0.013  |
| 12                     |                          |   | 0.29   | 0.19                            | 0.19  | 0.20                                   | 15.0   | 0.014  |
| 10                     |                          |   | 0.25   | 0.17                            | 0.17  | 0.18                                   | 12.0   | 0.015  |
| 8                      |                          |   | 0.20   | 0.15                            | 0.14  | 0.15                                   | 10.0   | 0.015  |
| 6                      |                          |   | 0.15   | 0.13                            | 0.11  | 0.11                                   | 8.5  | 0.015  |
| 4                      |                          |   | 0.11   | 0.08                            | 0.08  | 0.08                                   | 5.5  | 0.017  |
| 20                     | 0.95                     | 5.5   | 0.50   | 0.23                            | 0.25  | 0.26                                   | 36.5   | 0.007  |
| 18                     |                          |   | 0.48   | 0.23                            | 0.24  | 0.25                                   | 32.5   | 0.008  |
| 16                     |                          |   | 0.45   | 0.22                            | 0.23  | 0.24                                   | 28.0   | 0.009  |
| 14                     |                          |   | 0.42   | 0.21                            | 0.21  | 0.22                                   | 24.0   | 0.009  |
| 12                     |                          |   | 0.37   | 0.20                            | 0.19  | 0.20                                   | 20.5   | 0.010  |
| 10                     |                          |   | 0.31   | 0.18                            | 0.17  | 0.18                                   | 17.0   | 0.011  |
| 8                      |                          |   | 0.25   | 0.16                            | 0.15  | 0.16                                   | 14.0   | 0.012  |
| 6                      |                          |   | 0.19   | 0.13                            | 0.13  | 0.13                                   | 10.0   | 0.013  |
| 4                      |                          |   | 0.12   | 0.09                            | 0.10  | 0.10                                   | 7.0  | 0.014  |
| 20                     | 0.80                     | 3.9   | 0.61   | 0.24                            | 0.24  | 0.30                                   | 41.0   | 0.007  |
| 18                     |                          |   | 0.58   | 0.23                            | 0.23  | 0.29                                   | 36.5   | 0.008  |
| 16                     |                          |   | 0.54   | 0.22                            | 0.22  | 0.28                                   | 32.5   | 0.009  |
| 14                     |                          |   | 0.49   | 0.20                            | 0.20  | 0.27                                   | 26.5   | 0.010  |
| 12                     |                          |   | 0.44   | 0.18                            | 0.18  | 0.26                                   | 24.0   | 0.011  |
| 10                     |                          |   | 0.39   | 0.16                            | 0.16  | 0.24                                   | 20.0   | 0.012  |
| 8                      |                          |   | 0.31   | 0.14                            | 0.14  | 0.21                                   | 17.0   | 0.012  |
| 6                      |                          |   | 0.23   | 0.12                            | 0.12  | 0.16                                   | 13.0   | 0.014  |
| 4                      |                          |   | 0.15   | 0.09                            | 0.09  | 0.12                                   | 8.5  | 0.014  |
| 20                     | 0.64                     | 2.4   | 0.69   | 0.26                            | 0.23  | 0.25                                   | 43.0   | 0.006  |
| 18                     |                          |   | 0.65   | 0.25                            | 0.23  | 0.24                                   | 38.0   | 0.006  |
| 16                     |                          |   | 0.61   | 0.24                            | 0.22  | 0.24                                   | 33.5   | 0.007  |
| 14                     |                          |   | 0.56   | 0.23                            | 0.21  | 0.23                                   | 28.0   | 0.008  |
| 12                     |                          |   | 0.49   | 0.22                            | 0.20  | 0.22                                   | 23.0   | 0.009  |
| 10                     |                          |   | 0.42   | 0.21                            | 0.19  | 0.21                                   | 19.0   | 0.010  |
| 8                      |                          |   | 0.33   | 0.19                            | 0.17  | 0.18                                   | 15.0   | 0.012  |
| 6                      |                          |   | 0.25   | 0.16                            | 0.13  | 0.15                                   | 11.0   | 0.014  |
| 4                      |                          |   | 0.16   | 0.11                            | 0.10  | 0.10                                   | 7.0  | 0.014  |

TABLE III.—*Specimens (13.5 cm. long) of round "Crescent Tool Steel" of different brands.*

| Brand.                  | Diameter in centimeters. | Approximate weight in grammes. | Moment per gramme of magnetism induced in the specimen when placed "lengthwise" in a magnetic field of unit strength. |   |  | Semi-permanent magnetic moment per gramme in the case of the "glass-hard" magnet. | Permanent magnetic moment per gramme in the case of the seasoned magnet. | Approximate ratio of the induced moment caused by unit field to the permanent moment in the case of the seasoned magnet. |
|-------------------------|--------------------------|--------------------------------|---|---|--|---|--|--|
|                         |                          |                                | When "glass-hard" but not magnetized.   | When magnetized to saturation while "glass-hard." | In the condition of a seasoned magnet. |   |  |  |
| "D. R." -----           | 1.28                     | 133.5                          | 0.23  | 0.21  | 0.25                                   | 12  | 10   | 0.025  |
| " -----                 | 0.80                     | 53.0                           | 0.23  | 0.23  | 0.24                                   | 32  | 23   | 0.010  |
| " -----                 | 0.64                     | 34.6                           | 0.23  | 0.23  | 0.23                                   | 44  | 31   | 0.007  |
| " -----                 | 0.47                     | 19.0                           | 0.23  | 0.22  | 0.22                                   | 48  | 42   | 0.005  |
| " -----                 | 0.32                     | 8.4                            | 0.23  | 0.22  | 0.24                                   | 56  | 53   | 0.005  |
| "Crucible Steel" -----  | 1.28                     | 133.5                          | 0.22  | 0.22  | 0.22                                   | 18  | 16   | 0.014  |
| " -----                 | 0.80                     | 53.0                           | 0.24  | 0.24  | 0.24                                   | 31  | 22   | 0.011  |
| " -----                 | 0.64                     | 34.6                           | 0.28  | 0.26  | 0.28                                   | 38  | 30   | 0.009  |
| " -----                 | 0.50                     | 20.0                           | 0.31  | 0.31  | 0.31                                   | 46  | 34   | 0.009  |
| "Crescent Extra" -----  | 1.28                     | 133.5                          | 0.25  | 0.22  | 0.23                                   | 14  | 11   | 0.021  |
| " -----                 | 0.80                     | 53.0                           | 0.26  | 0.25  | 0.26                                   | 32  | 26   | 0.010  |
| " -----                 | 0.64                     | 34.6                           | 0.29  | 0.26  | 0.27                                   | 40  | 32   | 0.008  |
| " -----                 | 0.50                     | 20.0                           | 0.28  | 0.28  | 0.28                                   | 47  | 37   | 0.008  |
| "Double Crescent" ----- | 1.37                     | 157.0                          | 0.23  | 0.21  | 0.22                                   | 11  | 9  | 0.024  |
| " -----                 | 0.80                     | 53.0                           | 0.25  | 0.24  | 0.24                                   | 39  | 28   | 0.009  |
| " -----                 | 0.64                     | 34.6                           | 0.28  | 0.25  | 0.25                                   | 43  | 32   | 0.008  |
| " -----                 | 0.52                     | 21.2                           | 0.28  | 0.27  | 0.29                                   | 48  | 41   | 0.007  |
| "H. T. C." -----        | 0.80                     | 53.0                           | 0.30  | 0.30  | 0.30                                   | 21  | 31   | 0.010  |
| " -----                 | 0.64                     | 34.6                           | 0.34  | 0.32  | 0.32                                   | 51  | 42   | 0.008  |
| " -----                 | 0.53                     | 22.5                           | 0.36  | 0.32  | 0.32                                   | 63  | 51   | 0.006  |

TABLE IV.—*Tubular Magnets of Polished Crescent Drill Rod.*

| Length in centimeters. | Outside diameter in centimeters. | Diameter of hole in centimeters. | Weight of magnet in grammes. | Moment per gramme of the magnetism induced in the seasoned magnet when placed lengthwise in a field of unit intensity. | Permanent magnetic moment per gramme of the seasoned magnet. | Approximate ratio of the induced magnetic moment in the seasoned magnet caused by a unit field to the permanent moment of the magnet. |
|------------------------|----------------------------------|----------------------------------|------------------------------|--|--|---|
| 10.2                   | 1.28                             | 0.94                             | 42.9                         | 0.23   | 23   | 0.010   |
| 7.6                    | 1.28                             | 0.94                             | 31.8                         | 0.20   | 16   | 0.012   |
| 7.1                    | 0.95                             | 0.70                             | 14.8                         | 0.22   | 20   | 0.011   |
| 5.2                    | 0.95                             | 0.70                             | 11.1                         | 0.21   | 15   | 0.014   |



TABLE V.—*Twice-hardened Round Tool Steel.*

| Diameter in centimeters. | Length in centimeters. | Moment per gramme of the magnetism induced in the twice hardened but unseasoned and unmagnetized specimen when placed "lengthwise" in a unit field. | Moment per gramme of the magnetism induced in the twice hardened and seasoned magnet when placed "lengthwise" in a unit field. | Permanent magnetic moment per gramme of the twice hardened and finally seasoned magnet. |
|--------------------------|------------------------|---|--|---|
| 0.95                     | 20                     | 0.31  | 0.29   | 30.0  |
| 0.95                     | 18                     | 0.30  | 0.28   | 26.0  |
| 0.95                     | 15                     | 0.28  | 0.26   | 20.5  |
| 0.95                     | 10                     | 0.23  | 0.21   | 13.0  |
| 0.95                     | 6                      | 0.17  | 0.16   | 7.5   |
| 0.95                     | 4                      | 0.12  | 0.12   | 5.0   |

TABLE VI.—*Square Jessops Tool Steel.*

| Length in centimeters. | Moment per gramme of magnetism induced in the specimen when placed "lengthwise" in a unit field. |                    |  |  |  | Magnetic moment per gramme of the relaxed steel just after magnetization. | Permanent magnetic moment per gramme in the case of the seasoned magnet. | Approximate ratio of the induced magnetic moment caused by the permanent magnet in the case of the seasoned magnet. |
|------------------------|--|--------------------|--|--|--|---|--|---|
|                        | In the condition in which it was purchased.  | When "glass-hard." | After the temper had been hardened in the exposure for 6 hrs to steam at 100° C. | After the "relaxed" steel had been magnetized to saturation. | In the condition of a seasoned magnet. |   |  |   |
| 4                      | 0.12   | 0.10               | 0.10   | 0.08   | 0.10                                   | 4.5   | 4.5  | 0.022   |
| 6                      | 0.18   | 0.14               | 0.14   | 0.12   | 0.14                                   | 7.0   | 7.0  | 0.019   |
| 8                      | 0.24   | 0.18               | 0.18   | 0.15   | 0.18                                   | 11.5  | 11.5   | 0.016   |
| 10                     | 0.29   | 0.21               | 0.21   | 0.17   | 0.21                                   | 16.5  | 16.0   | 0.013   |
| 12                     | 0.34   | 0.23               | 0.23   | 0.19   | 0.23                                   | 21.0  | 20.0   | 0.011   |
| 14                     | 0.39   | 0.25               | 0.25   | 0.20   | 0.25                                   | 26.0  | 24.5   | 0.010   |
| 16                     | 0.44   | 0.27               | 0.27   | 0.21   | 0.27                                   | 31.0  | 29.0   | 0.009   |
| 18                     | 0.48   | 0.28               | 0.28   | 0.22   | 0.28                                   | 36.0  | 33.0   | 0.009   |
| 20                     | 0.52   | 0.29               | 0.29   | 0.23   | 0.30                                   | 41.0  | 38.0   | 0.008   |

Cross-section = 0.67 sq. cm. Weight per cm. of length = 5.28 grammes.

TABLE VII.—*Jessops Flat Tool Steel.*

| Length in centimeters. | Moment per gramme of magnetism induced in the seasoned magnet when placed "lengthwise" in a unit field. | Permanent magnetic moment per gramme of the seasoned magnet. | Approximate ratio of the induced magnetic moment caused by the seasoned magnet by a unit field to the permanent moment of the magnet. |
|------------------------|---|--|---|
| 6                      | 0.18  | 11.0   | 0.018   |
| 8                      | 0.22  | 15.0   | 0.015   |
| 10                     | 0.24  | 18.5   | 0.013   |
| 15                     | 0.29  | 27.5   | 0.011   |
| 20                     | 0.33  | 36.5   | 0.009   |

Weight per centimeter of length = 3.9 grammes.  
Cross-section = 1.6 cm. × 0.32 cm.

The Jefferson Physical Laboratory,  
Cambridge, Mass., August, 1896.

ART. LII.—*On the Application of Certain Organic Acids to the Estimation of Vanadium*; by PHILIP E. BROWNING and RICHARD J. GOODMAN.

[Contributions from the Kent Chemical Laboratory of Yale University. —LIX]

IN a former paper\* by one of us a method for the determination of vanadium was described in which tartaric acid was used to reduce vanadic acid to the condition of the tetroxide. The method may be briefly outlined as follows:

Measured and weighed portions of a solution of ammonium vanadate, the standard of which had been determined by the evaporation and ignition of definite portions, were treated with tartaric acid in excess and boiled, when the appearance of the deep blue color indicated the reduction to the condition of the tetroxide. After cooling, the solution was neutralized with potassium bicarbonate and a moderate excess of that reagent added. To the alkaline solution an excess of a standard solution of iodine was added and the whole allowed to stand about one hour, when no further bleaching of the iodine was noticed.† The excess of iodine was then destroyed with a standard solution of arsenious oxide, starch was added, and the blue color obtained with a few drops of the iodine solution. The total amount of iodine used, less the amount equivalent to the arsenious oxide solution used, is the amount necessary to oxidize the vanadium from the condition of the tetroxide to that of the pentoxide, from which, according to the following equation, can be calculated the amount of vanadium present:



The work to be described in this paper is in part an application of the work described in the paper above mentioned to a series of determinations of vanadium in the presence of molybdenum and tungsten. The solution of vanadium used was one of ammonium vanadate, and the standard was determined by evaporating and igniting, in the presence of a drop of nitric acid, measured and weighed portions, the mean of closely agreeing results being taken as the standard. Our first series of determinations was by the method previously described, that being the natural starting point for the work contemplated. The results follow in the table:

\* Zeitschr. für anorgan. Chem. vii, 158.

† These determinations are best made in small Erlenmeyer beakers, closed with paraffin-coated corks while standing with iodine.

|      | V <sub>2</sub> O <sub>5</sub> taken.<br>gram. | V <sub>2</sub> O <sub>5</sub> found.<br>gram. | Error.<br>gram. | Tartaric acid.<br>gram. |
|------|---|---|-----------------|-------------------------|
| (1)  | 0.1621  | 0.1618  | 0.0003—         | 2                       |
| (2)  | 0.1620  | 0.1624  | 0.0004+         | 2                       |
| (3)  | 0.1614  | 0.1622  | 0.0008+         | 2                       |
| (4)  | 0.1619  | 0.1606  | 0.0013—         | 1                       |
| (5)  | 0.1604  | 0.1597  | 0.0007—         | 2                       |
| (6)  | 0.1618  | 0.1615  | 0.0003—         | 3                       |
| (7)  | 0.1298  | 0.1305  | 0.0007+         | 1                       |
| (8)  | 0.1294  | 0.1297  | 0.0003+         | 1                       |
| (9)  | 0.1618  | 0.1618  | 0.0000±         | 2                       |
| (10) | 0.2588  | 0.2575  | 0.0013—         | 3                       |
| (11) | 0.2722  | 0.2726  | 0.0004+         | 2                       |
| (12) | 0.3273  | 0.3269  | 0.0004—         | 2                       |

We next tried the effect of treating a solution of sodium tungstate in the same manner. We found that after the boiling with tartaric acid, neutralizing, adding iodine and allowing to stand as before, the amount of free iodine present, as shown by the amount of arsenious oxide solution necessary to destroy it was the same as that originally added, showing that no reduction had taken place. Accordingly a series of determinations of vanadium in the presence of tungsten was made which is recorded in the following table:

|     | V <sub>2</sub> O <sub>5</sub> taken.<br>gram. | V <sub>2</sub> O <sub>5</sub> found.<br>gram. | Error.<br>gram. | Sodium tungstate.<br>gram. | Tartaric acid.<br>gram. |
|-----|---|---|-----------------|----------------------------|-------------------------|
| (1) | 0.1618  | 0.1615  | 0.0003—         | 1                          | 3                       |
| (2) | 0.1615  | 0.1606  | 0.0009—         | 1                          | 3                       |
| (3) | 0.1618  | 0.1624  | 0.0006+         | 1                          | 3                       |
| (4) | 0.1619  | 0.1624  | 0.0005+         | 1                          | 3                       |
| (5) | 0.1627  | 0.1623  | 0.0004—         | 1                          | 3                       |
| (6) | 0.1621  | 0.1624  | 0.0003+         | 1                          | 4                       |
| (7) | 0.2587  | 0.2574  | 0.0013—         | 1                          | 4                       |
| (8) | 0.2587  | 0.2589  | 0.0002+         | 1                          | 4                       |

The results above show that vanadium may be easily determined by this method in the presence of tungsten without any evident interfering action on the part of the latter element.

When the same method of treatment was applied in the presence of molybdenum in the form of ammonium molybdate, the majority of the determinations gave large plus errors, and a few experiments made with the molybdate alone seemed to show a noticeable reduction of the molybdic acid. In the following table the results are tabulated. In experiments (3), (4) and (5) the mixtures were not boiled with tartaric acid, but warmed on a steam bath, with, however, no very apparent prevention of the reducing action.



|      | V <sub>2</sub> O <sub>5</sub> taken.<br>gram. | V <sub>2</sub> O <sub>5</sub> found.<br>gram. | Error.<br>gram. | Ammonium<br>molybdate.<br>gram. | Tartaric<br>acid<br>gram. |
|------|---|---|-----------------|---------------------------------|---------------------------|
| (1)  | 0·1620  | 0·1790  | 0·0170 +        | 1                               | 2                         |
| (2)  | 0·1624  | 0·1619  | 0·0005 —        | 1                               | 2                         |
| (3)  | 0·1294  | 0·1416  | 0·0253 +        | 1                               | 2                         |
| (4)  | 0·1296  | 0·1361  | 0·0065 +        | 1                               | 2                         |
| (5)  | 0·1291  | 0·1312  | 0·0021 +        | 1                               | 2                         |
| (6)  | 0·1293  | 0·1324  | 0·0031 +        | 1                               | 2                         |
| (7)  | 0·1636  | 0·1760  | 0·0124 +        | 1                               | 2                         |
| (8)  | 0·1640  | 0·1724  | 0·0084 +        | 1                               | 2                         |
| (9)  | 0·1622  | 0·1624  | 0·0002 +        | 1                               | 3                         |
| (10) | 0·1622  | 0·1632  | 0·0010 +        | 1                               | 3                         |
| (11) | 0·1619  | 0·1879  | 0·0260 +        | 1                               | 3                         |
| (12) | 0·1292  | 0·1360  | 0·0068 +        | 1                               | 3                         |
| (13) | 0·1860  | 0·1917  | 0·0057 +        | 1                               | 3                         |
| (14) | 0·3274  | 0·3733  | 0·0459 +        | 1                               | 4                         |
| (15) | 0·2324  | 0·2383  | 0·0059 +        | 1                               | 4                         |

We next tried the action of tartaric acid upon the vanadium solution in the cold and found that the reduction could be carried on to completion under these conditions if the tartaric acid was in large excess, the time sufficient and the volume of the solution small. The following series was made to determine these points:

|     | V <sub>2</sub> O <sub>5</sub> taken.<br>gram. | V <sub>2</sub> O <sub>5</sub> found.<br>gram. | Error.<br>gram. | Time.<br>days. | Tartaric<br>acid.<br>gram. | Total vol.<br>cm <sup>3</sup> . |
|-----|---|---|-----------------|----------------|----------------------------|---------------------------------|
| (1) | 0·1646  | 0·1649  | 0·0003 +        | 1              | 4                          | 25                              |
| (2) | 0·1640  | 0·1606  | 0·0034 —        | 1              | 4                          | 65                              |
| (3) | 0·1293  | 0·1264  | 0·0029 —        | 2              | 3                          | 55                              |
| (4) | 0·1633  | 0·1628  | 0·0005 —        | 2              | 4                          | 65                              |
| (5) | 0·1293  | 0·1288  | 0·0005 —        | 3              | 2·5                        | 50                              |
| (6) | 0·1298  | 0·1299  | 0·0001 +        | 3              | 2·5                        | 50                              |
| (7) | 0·1295  | 0·1279  | 0·0016 —        | 3              | 3                          | 55                              |
| (8) | 0·1617  | 0·1597  | 0·0020 —        | 4              | 2                          | 70                              |
| (9) | 0·1623  | 0·1622  | 0·0001 —        | 4              | 3                          | 80                              |

Solutions containing sodium tungstate and ammonium molybdate were allowed to stand from one to four days with varying amounts of tartaric acid without giving any evidence of reduction.

In the series which follows may be seen the results of a number of determinations of vanadium in the presence of molybdenum and tungsten made in the cold and allowed to stand from one\* to four days. It will be noticed that the results on standing one day with five grams of tartaric acid are

\* Some of the determinations designated in the table as having stood one day in reality stood only about fifteen hours, from 6 P. M. to 9 A. M.

for the most part satisfactory, and an increase in the length of time does not cause any apparent reduction of the molybdenum.

|      | V <sub>2</sub> O <sub>5</sub> taken.<br>gram. | V <sub>2</sub> O <sub>5</sub> found.<br>gram. | Error.<br>gram. | Ammonium<br>molybdate.<br>gram. | Sodium<br>tung-<br>state.<br>gram. | Time in<br>days. | Total Tartaric<br>volume.<br>cm <sup>3</sup> . | acid.<br>gram. |
|------|---|---|-----------------|---------------------------------|------------------------------------|------------------|--|----------------|
| (1)  | 0·1552  | 0·1558  | 0·0006 +        | --                              | --                                 | 1                | 25   | 5              |
| (2)  | 0·1289  | 0·1301  | 0·0012 +        | --                              | --                                 | 1                | 25   | 5              |
| (3)  | 0·2583  | 0·2587  | 0·0004 +        | --                              | --                                 | 1                | 50   | 5              |
| (4)  | 0·1293  | 0·1299  | 0·0006 ÷        | 1·                              | --                                 | 1                | 25   | 6              |
| (5)  | 0·2582  | 0·2591  | 0·0009 +        | 1·                              | --                                 | 1                | 50   | 6              |
| (6)  | 0·2582  | 0·2588  | 0·0006 +        | 1·                              | --                                 | 1                | 50   | 5              |
| (7)  | 0·1297  | 0·1308  | 0·0011 +        | 1·                              | --                                 | 1                | 25   | 5              |
| (8)  | 0·1291  | 0·1289  | 0·0002 -        | --                              | 1                                  | 1                | 25   | 6              |
| (9)  | 0·2582  | 0·2568  | 0·0014 -        | --                              | 1                                  | 1                | 50   | 5              |
| (10) | 0·1293  | 0·1299  | 0·0006 +        | 1·                              | 1                                  | 1                | 25   | 8              |
| (11) | 0·2582  | 0·2579  | 0·0003 -        | 1·                              | 1                                  | 1                | 50   | 5              |
| (12) | 0·1550  | 0·1538  | 0·0012 -        | --                              | --                                 | 2                | 25   | 5              |
| (13) | 0·1556  | 0·1545  | 0·0011 -        | --                              | --                                 | 2                | 25   | 5              |
| (14) | 0·1289  | 0·1296  | 0·0007 +        | --                              | --                                 | 2                | 25   | 5              |
| (15) | 0·1549  | 0·1527  | 0·0022 -        | 0·5                             | --                                 | 2                | 25   | 5              |
| (16) | 0·1553  | 0·1548  | 0·0005 -        | 1·                              | --                                 | 2                | 25   | 5              |
| (17) | 0·1556  | 0·1554  | 0·0002 -        | 1·                              | --                                 | 2                | 25   | 5              |
| (18) | 0·1293  | 0·1310  | 0·0017 +        | 1·                              | --                                 | 2                | 25   | 6              |
| (19) | 0·1295  | 0·1299  | 0·0004 +        | --                              | 1·                                 | 2                | 25   | 6              |
| (20) | 0·1293  | 0·1289  | 0·0004 -        | 1·                              | 1·                                 | 2                | 25   | 7              |
| (21) | 0·1293  | 0·1301  | 0·0008 +        | --                              | --                                 | 3                | 25   | 5              |
| (22) | 0·1289  | 0·1299  | 0·0010 +        | 0·5                             | --                                 | 3                | 25   | 5              |
| (23) | 0·1293  | 0·1292  | 0·0001 -        | 1·                              | --                                 | 3                | 25   | 7              |
| (24) | 0·1556  | 0·1567  | 0·0011 +        | 1·                              | --                                 | 3                | 30   | 5              |
| (25) | 0·1291  | 0·1289  | 0·0002 -        | 1·                              | 1·                                 | 3                | 25   | 7              |
| (26) | 0·1550  | 0·1557  | 0·0007 +        | --                              | --                                 | 4                | 25   | 5              |
| (27) | 0·1554  | 0·1557  | 0·0003 +        | 1·                              | --                                 | 4                | 25   | 5              |
| (28) | 0·1556  | 0·1557  | 0·0001 +        | 0·5                             | --                                 | 4                | 25   | 5              |

Friedham\* has shown that vanadium is reduced from the condition of the pentoxide to that of the tetroxide by boiling with oxalic acid. The reduction is so complete that he has developed a method for the estimation of vanadium upon this reaction and shows that it may be applied in the presence of molybdenum and tungsten, the acids of these elements not being reduced by the oxalic acid. When the vanadic acid is reduced the oxalic acid is oxidized and a definite amount of carbon dioxide evolved according to the reaction.



This carbon dioxide Friedheim conducts by an appropriate

\* Zeitschr. für anorgan. Chem. i, 312.

form of apparatus into potassium hydroxide and weighs. From this weight the amount of vanadic acid originally present may be readily calculated.

We have applied the method of oxidation with standard iodine described in the tartaric acid process to the residue after boiling with oxalic acid. The method of treatment was identical with that outlined at the beginning of this paper. The results which follow in the table are for the most part satisfactory and the method is certainly more easily applied than Friedheim's process, the potassium hydroxide absorption apparatus being unnecessary.

|      | V <sub>2</sub> O <sub>5</sub> taken. | V <sub>2</sub> O <sub>5</sub> found. | Error.   | Oxalic acid. | Ammonium tung- | Sodium |
|------|--------------------------------------|--------------------------------------|----------|--------------|----------------|--------|
|      | gram.                                | gram.                                | gram.    | gram.        | molybdate.     | state. |
|      |                                      |                                      |          |              | gram.          | gram.  |
| (1)  | 0.1806                               | 0.1803                               | 0.0003 — | 1            |                |        |
| (2)  | 0.1950                               | 0.1955                               | 0.0005 + | 1            |                |        |
| (3)  | 0.1959                               | 0.1955                               | 0.0004 — | 1            |                |        |
| (4)  | 0.1950                               | 0.1959                               | 0.0009 + | 1            |                |        |
| (5)  | 0.1954                               | 0.1977                               | 0.0023 + | 1            |                |        |
| (6)  | 0.1956                               | 0.1960                               | 0.0004 + | 1            |                |        |
| (7)  | 0.1956                               | 0.1964                               | 0.0008 + | 1            |                |        |
| (8)  | 0.1956                               | 0.1957                               | 0.0001 + | 1            |                |        |
| (9)  | 0.3900                               | 0.3899                               | 0.0001 — | 2            |                |        |
| (10) | 0.3897                               | 0.3917                               | 0.0020 + | 2            |                |        |
| (11) | 0.3903                               | 0.3905                               | 0.0002 + | 2            |                |        |
| (12) | 0.1954                               | 0.1959                               | 0.0005 + | 2            | 1              |        |
| (13) | 0.1957                               | 0.1960                               | 0.0003 + | 2            | 1              |        |
| (14) | 0.1954                               | 0.1961                               | 0.0007 + | 2            | 1              |        |
| (15) | 0.1806                               | 0.1818                               | 0.0012 + | 3            | --             |        |
| (16) | 0.1807                               | 0.1827                               | 0.0020 + | 3            | --             |        |
| (17) | 0.1809                               | 0.1803                               | 0.0006 — | 3            | 1              |        |
| (18) | 0.1956                               | 0.1961                               | 0.0005 + | 3            | --             | 1      |
| (19) | 0.3611                               | 0.3617                               | 0.0006 + | 5            | --             | --     |
| (20) | 0.3616                               | 0.3626                               | 0.0010 + | 5            | 1              | --     |

Having applied successfully both tartaric acid and oxalic acid in the manner described, the action of citric acid applied in the same manner suggested itself as a fitting conclusion to the study of the action of this class of organic acids. In this case, as in the others, the reduction of the vanadic acid is easily and quickly effected, but the oxidation with the iodine is slower than in the presence of alkaline oxalates and tartrates. In the case of oxalic acid on standing about fifteen minutes with the excess of iodine, when tartaric acid has been used, the bleaching of the iodine continues from thirty to forty-five minutes, but in the presence of the alkaline citrate the time required is fully an hour. A large excess of tartaric or oxalic acids does not seem to materially affect the results,



but in the use of citric acid it is advisable to avoid a large excess, which tends to give high results. Accordingly in the following series of experiments it will be noticed that the amounts of citric acid do not exceed two grams except where ammonium molybdate or sodium tungstate are present, when the ammonium or sodium base combines with part of the free acid. The results follow :

| $V_2O_5$ taken.<br>gram. | $V_2O_5$ found.<br>gram. | Error.<br>gram. | Citric acid.<br>gram. | Ammonium tung-<br>molybdate.<br>gram. | Sodium<br>tung-<br>state.<br>gram. |
|--------------------------|--------------------------|-----------------|-----------------------|---------------------------------------|------------------------------------|
| (1) 0.1956               | 0.1956                   | 0.0000 ±        | 1                     |                                       |                                    |
| (2) 0.3905               | 0.3921                   | 0.0016 +        | 2                     |                                       |                                    |
| (3) 0.1960               | 0.1960                   | 0.0000 ±        | 1                     |                                       |                                    |
| (4) 0.1953               | 0.1960                   | 0.0007 +        | 1                     |                                       |                                    |
| (5) 0.2088               | 0.2082                   | 0.0006 —        | 2                     |                                       |                                    |
| (6) 0.2100               | 0.2098                   | 0.0002 —        | 2                     |                                       |                                    |
| (7) 0.2092               | 0.2107                   | 0.0015 +        | 1                     |                                       |                                    |
| (8) 0.2092               | 0.2107                   | 0.0015 +        | 2                     |                                       |                                    |
| (9) 0.2096               | 0.2082                   | 0.0014 —        | 2                     | 0.5                                   |                                    |
| (10) 0.2099              | 0.2116                   | 0.0017 +        | 3                     | 0.5                                   | --                                 |
| (11) 0.2005              | 0.2101                   | 0.0006 +        | 2                     | --                                    | 0.5                                |
| (12) 0.2099              | 0.2095                   | 0.0004 —        | 3                     | --                                    | 0.5                                |

The mode of proceeding in the estimation of vanadium by the use of either tartaric, oxalic or citric acids may be briefly summarized as follows: To a solution of a vanadate with or without a tungstate or molybdate, add approximately one gram of the acid for every tenth of a gram of substance to be determined. Heat the solution to boiling, except in case tartaric acid be present with molybdic acid, when digestion for from fifteen to twenty-four hours in the cold should be substituted. To the cold liquid add about five grams of potassium bicarbonate for every gram of acid used. Add iodine in slight excess and set aside until no further bleaching is noticeable. Destroy the excess of iodine with arsenious oxide solution, add starch, and titrate back with standard iodine. The total amount of iodine used less the equivalent of the arsenious oxide is the measure of the oxidation.

I have found it of advantage, when starting with a new solution of the vanadate, to make one determination roughly and to get from this rough determination the proportions of acid and iodine to be used in the determinations to follow. Large amounts of the acid and a large excess of the iodine have been employed in many determinations without any apparent unfavorable effect upon the results. The tendency, however, under these circumstances is toward plus errors, which may be avoided by following the above directions.

June, 1896.

ART. LIII.—*The Determination of Oxygen in Air and in Aqueous Solution*; by D. ALBERT KREIDER.

[Contributions from the Kent Chemical Laboratory of Yale University, LX.]

WHILE there is little to be hoped for by way of improvement in the accuracy of present known methods for the determination of oxygen in the air, some choice as to manipulation may nevertheless be desirable, and a process which is not limited wholly to the methods and apparatus of ordinary gas analysis will doubtless often be found serviceable.

The very satisfactory results which I have obtained in the determination of perchlorates by the action of the liberated oxygen upon hydriodic acid through the medium of nitric oxide\* has led me to test this action upon the oxygen of the air, where only the smaller amount of oxygen and its greater dilution with nitrogen might be expected to be unfavorable. However with the apparatus and manipulation herein described it will be seen that the method affords a means for the determination of the oxygen of the air or of dissolved oxygen with ease and rapidity and with sufficient accuracy for all practical purposes.

The method in brief is simply the conducting of a known volume of air through a strong solution of hydriodic acid in the presence of nitric oxide; subsequently neutralizing the acid with potassium bicarbonate and titrating the liberated iodine with standard decinormal arsenic solution from which the equivalent volume of oxygen is readily calculated. By several simple devices, to be described, all calculations may be done away with and the percentage of oxygen seen immediately by the volume of arsenic solution required for the titration.

The volume of oxygen found by means of the arsenic solution is, of course, under the standard conditions of temperature and pressure ( $0^{\circ}$  and  $760^{\text{mm}}$ ), and it is therefore essential either to calculate this volume into that which it would occupy under the conditions of the experiment, or to reduce to the standard conditions of temperature and pressure the volume of air taken. The latter plan is the more satisfactory since by Lunge's ingenious device† the reduction can be readily effected without any calculation and independently of changing temperature and pressure. For my purpose the following arrangement of two burettes answered admirably. One burette graduated to  $120^{\text{cm}^3}$  contained over mercury the same

\* This Journal, I, 287.

† Zeitschr. für Ang. Chem. 1890, 139.

volume of moist air which 100<sup>cm</sup><sup>3</sup> of air at 0° and 760<sup>mm</sup> would occupy under the given conditions; this standard being very carefully determined. By means of a T-tube this standard burette was placed between and in connection with the burette in which the volume of air to be analyzed was measured, and a movable reservoir of mercury. Both burettes were firmly fastened to a movable iron rod and the zero marks accurately adjusted to the same level. By drawing into the measuring burette a volume of air greater than that required—for which purpose a small bulb was attached to the lower end of the burette, and then by raising the reservoir of mercury, compressing the air in the standard tube to the 100<sup>cm</sup><sup>3</sup> mark, at the same time allowing the excess of air to escape from the measuring burette, exactly 100<sup>cm</sup><sup>3</sup> of air under the standard conditions of temperature and pressure was obtained. To facilitate the adjustment, two strips of wood were fastened to the rubber connection by means of screw pinch-cocks in such a way that by closing one pinch-cock the flow of mercury from the reservoir could be shut off, and then by gradually tightening the other pinch-cock the mercury would be forced out of the rubber, and thus an easy and accurate adjustment to the 100<sup>cm</sup><sup>3</sup> mark be secured.

The apparatus in which the action of the oxygen upon hydriodic acid was effected consisted of a 300<sup>cm</sup><sup>3</sup> bulb pipette, both ends of which were cut off short and sealed to glass stop-cocks. The tube from one of the stop-cocks was cut off short after being tapered and restricted so as to hold a rubber connector tightly, while the tube from the other stop-cock was left sufficiently long to reach to the bottom of a 500<sup>cm</sup><sup>3</sup> Erlenmeyer beaker. These tubes are preferably of about 3<sup>mm</sup> bore, since for the several connections all air may be expelled from tubes of this size by displacement with water. In order to expel all air from the flask, instead of passing a current of carbon dioxide as was done in the determination of perchlorates, time was saved by first filling the flask with water, which was then displaced by pure carbon dioxide (prepared as described below) and the flask subsequently exhausted, which was accomplished instantaneously by the device described in the article on perchlorates. The required amounts of potassium iodide solution, hydrochloric acid and nitric oxide were drawn in in the order named, after which the measured volume of air was gradually admitted while the bulb was constantly agitated so as to keep the hydriodic acid continually renewed along the surface of the bulb. The shaking was continued for a minute or two until the action was completed, when a dilute solution of potassium bicarbonate was admitted. The



carbon dioxide liberated forces the liquid from the bulb into a beaker which contains bicarbonate in amount sufficient, as previously determined, to neutralize all the acid taken. When the exit is too slow more bicarbonate may be admitted through the other stop-cock, and after neutralization has been completed the bulb may be washed out without any danger from the admission of air.

All the water employed, both for the solution of potassium iodide and for the various connections, was free of oxygen. It was prepared by filling a three liter flask with distilled water and boiling until the volume of the liquid was reduced about one-third, when the flask was closed by a doubly perforated rubber stopper and fitted as a wash bottle. By means of the tube which reached below the surface of the water, pure carbon dioxide was passed through while the water was still boiling, which together with the escaping steam was sure to expel all oxygen. Then the heat was removed and the current of carbon dioxide continued until the boiling ceased, when the escape tube was closed by a piece of rubber tubing and screw pinch-cock. As the water cooled it was well shaken while still in connection with the carbon dioxide generator, and thus became saturated with the gas, which was then pumped in under considerable pressure by the little hand pump described in a previous paper from this laboratory. By this means the water could be drawn as needed without the introduction of any air. The escape tube was provided with a rubber tube and screw pinch-cock, and a long, slender nozzle which could be inserted into the tubes of the absorption apparatus. A bottle thus charged sufficed for all the determinations and required only an occasional supply of carbon dioxide when large draughts of water were required for making the potassium iodide solution.

The potassium iodide solution was made up to contain one gram of the salt in thirty cubic centimeters of water, and was contained in convenient form in an ordinary wide-mouthed bottle fitted as a wash bottle, and graduated approximately for each thirty cubic centimeter's volume—the amount usually taken. The potassium iodide was weighed into the bottle, which was then closed and all air expelled by a current of carbon dioxide, when the desired amount of water, free of oxygen, was drawn in, and attachment again made with the carbon dioxide generator. After allowing the gas to pass for several minutes the exit was closed and the gas pumped in by the little hand pump. Inasmuch as this solution, when it was used, was drawn into an exhausted bulb, the bottle could be emptied without ever exposing its contents to the air.

Nitric oxide was generated very satisfactorily according to Professor Gooch's method—by the action of nitric acid upon globules of copper in a Kipp generator. When the nitric acid is diluted with an equal volume of water the evolution of the gas is sufficiently rapid without the application of heat, but contamination by the higher oxide is more likely. However, since it is necessary, in order to be certain of purity, to pass the gas through an acidified solution of potassium iodide before applying it to the determination of oxygen, whatever higher oxide may be present will be reduced. By passing the gas, as it issued from the generator, through a set of Geisler bulbs containing an acidified solution of potassium iodide and washing with potassium iodide solution, the perfectly purified gas was obtained. Theoretically, only a small amount of the nitric oxide is required for the transference of the oxygen to the hydriodic acid, but when too little is taken the action is very slow. On the other hand, too large an amount relieves the vacuum to such an extent as to interfere with the introduction of the air. A little device to measure the volume of gas taken was therefore attached to the generator. It consisted of a tube filled with water and roughly graduated for every five cubic centimeters, so attached to the generator that the gas would enter by displacement of the water, which would descend to a lower bulb, and as the gas was withdrawn the water would again take its place. Fifteen cubic centimeters of the gas was found a convenient and satisfactory amount for the analysis.

Carbon dioxide was generated in a Kipp generator, the acid and marble of which had been previously boiled and contained a little cuprous chloride. To remove a trace of reducing matter which the gas was found to contain, it was first passed through a solution of iodine and washed with potassium iodide.

For the titration a decinormal solution of arsenious oxide (4.95 gms. to the liter) was employed: one cubic centimeter being equal to  $0.559846\text{cm}^3$  of oxygen at  $0^\circ$  and  $760\text{mm}$  when the weight of a liter of oxygen at  $0^\circ$  and  $760\text{mm}$  is taken as  $1.42895$  gms. When the volume of air taken is  $100\text{cm}^3$  under standard conditions of temperature and pressure, as obtained by Lunge's device, the following table, calculated for the volume of oxygen equivalent to the volume of arsenic solution, shows directly the percentage of oxygen corresponding to the reading of the burette. The correction necessary for the fraction of a tenth of a cubic centimeter of the arsenic solution is obtained with sufficient accuracy by simply multiplying by  $0.005$ .

*Relation of Arsenic to Oxygen.*

| $\frac{n}{10}\text{As}_2\text{O}_3$<br>cm <sup>3</sup> . | Oxygen equivalent<br>at 0° and 760 <sup>mm</sup> .<br>cm <sup>3</sup> . | Correction for<br>0.01 cm <sup>3</sup> $\frac{n}{10}\text{As}_2\text{O}_3$ . |
|--|---|--|
| 37.0   | 20.714  | 0.005  |
| 37.1   | 20.770  |  |
| 37.2   | 20.826  |  |
| 37.3   | 20.882  |  |
| 37.4   | 20.938  |  |
| 37.5   | 20.994  |  |
| 37.6   | 21.050  |  |
| 37.7   | 21.106  |  |
| 37.8   | 21.162  |  |
| 37.9   | 21.218  |  |
| 38.0   | 21.274  |  |

Table I shows the results obtained in a series of determinations. Experiments 1 to 11 inclusive were made upon portions of air collected over water on March 28, measured in an ordinary gas burette and reduced to the standard conditions of temperature and pressure. The remainder of the determinations were made upon air collected on April 8th, each portion having been measured in the apparatus described, for the reduction to standard conditions.

TABLE I.

|     | Vol. of Air reduced to<br>0° and 760 <sup>mm</sup> .<br>cm <sup>3</sup> . | $\frac{n}{10}\text{As}_2\text{O}_3$<br>required.<br>cm <sup>3</sup> . | Vol. of Oxygen found<br>at 0° and 760 <sup>mm</sup> .<br>cm <sup>3</sup> . | Per cent of<br>Oxygen in<br>Air. |
|-----|---|---|--|----------------------------------|
| 1.  | 91.18   | 34.06   | 19.07  | 20.91                            |
| 2.  | 91.73   | 34.47   | 19.30  | 21.04                            |
| 3.  | 90.84   | 34.25   | 19.17  | 21.11                            |
| 4.  | 90.60   | 34.20   | 19.16  | 21.13                            |
| 5.  | 86.06   | 32.55   | 18.22  | 21.17                            |
| 6.  | 85.96   | 32.40   | 18.14  | 21.10                            |
| 7.  | 86.49   | 32.53   | 18.21  | 21.06                            |
| 8.  | 87.85   | 33.00   | 18.47  | 21.03                            |
| 9.  | 44.17   | 16.60   | 9.29   | 21.04                            |
| 10. | 44.11   | 16.70   | 9.35   | 21.19                            |
| 11. | 44.54   | 16.80   | 9.41   | 21.12                            |
| 12. | 100.00  | 37.44   | 20.96  | 20.96                            |
| 13. | 100.00  | 37.54   | 21.01  | 21.01                            |
| 14. | 100.00  | 37.50   | 20.99  | 20.99                            |
| 15. | 100.00  | 37.57   | 21.03  | 21.03                            |
| 16. | 100.00  | 37.47   | 20.97  | 20.97                            |
| 17. | 100.00  | 37.50   | 20.99  | 20.99                            |



No correction was found necessary for the blank determinations, since when boiled water was used the solution was only faintly colored with iodine, which requires only a drop of arsenic solution to bleach it. As is evident from the table, the determinations according to this method are not reliable beyond 0.05 per cent, but for practical purposes this is sufficiently accurate. For the sake of comparison two determinations by the pyrogallic acid method were made upon a portion of the same air used in the last experiments, the results being 20.93 and 20.85 per cent respectively. While the pyrogallic acid method is capable of much greater accuracy when applied in Hempel's improved apparatus, in ordinary burettes it will probably not yield more closely agreeing results than the above method.

*Determination of dissolved Oxygen.*—A determination of oxygen dissolved in water can be completed by the above method in about ten minutes by means of the apparatus illustrated by the accompanying figure.



The apparatus consisted of a flask of about 300<sup>cm</sup><sup>3</sup> capacity, into the bottom of which was sealed a stop-cock with a long exit tube. Upon the neck was cut the fiducial circle *c* and immediately above this stop-cock *e* was sealed as shown. The neck of the flask was drawn out and sealed to stop-cock *d* and the bulb, *a*, of about 30<sup>cm</sup><sup>3</sup> capacity blown in it. The capacity of the apparatus between stop-cock, *b*, and the fiducial mark, *c*, was carefully determined.

The manipulation for the determination of dissolved oxygen was as follows: The flask was held in the position shown by a clamp fastened to a movable support. Stop-cock *b* being closed, the water was admitted through *e* and the air allowed to escape through *d* until the level of water was that indicated by the line *f*. (When the water to be examined is not saturated with air, the flask must first be filled with carbon dioxide and the water entered by replacement of that gas.) With *d* closed, sufficient water was allowed to escape through *b* to bring the surface to *e*, which was then closed. The nitric oxide generator was then attached to *d*, and by opening *b* the gas was allowed to replace the water until the meniscus coincided with *c*, when *d* was closed and the generator disconnected. Two cubic centimeters of strong hydrochloric acid were introduced through *e* by expelling nitric oxide through *d*, in which a drop of water formed an effective trap to prevent the entrance of air. Then the potassium iodide was admitted in the same way. The solution of iodide for this purpose was free of oxygen and contained one gram in three cubic centimeters. It was kept under pressure of carbon dioxide in the bottle previously

described, and by means of a long nozzle could be conducted to the bottom of *eh* and thus be admitted with but momentary and slight contact with the air. The tube *eh* contained approximately three cubic centimeters. With all the stop-cocks closed, the flask was inverted several times and thoroughly shaken, at the same time washing out the ends of the stop-cocks with distilled water. After again placing the apparatus in its position, enough potassium bicarbonate solution was admitted through *e* to expel all the nitric oxide through *d*; the bulb, *a*, holding sufficient of the bicarbonate to neutralize all the acid taken. The bicarbonate being heavier quickly diffuses through the contents of the flask and neutralizes the acid; *d* and *e* are kept closed for a minute with *b* open so as to allow sufficient of the liquid to escape into a beaker containing some bicarbonate to provide space for the carbon dioxide evolved. Then the flask is washed out and its contents titrated with arsenic.

The bleaching, by the aid of starch for the final reaction, can be accurately read to a single drop. Usually the reading was verified by adding a drop of  $\frac{N}{10}$  iodine solution, which produced the characteristic color.

Table II gives the results of a series of determinations.

TABLE II.

| Vol. of Water taken.<br>cm <sup>3</sup> . | Temperature.<br>—° C. | As <sub>2</sub> O <sub>3</sub><br>required.<br>cm <sup>3</sup> . | Vol. of Oxygen dissolved<br>in 1000 cm <sup>3</sup> of water<br>at 760 <sup>mm</sup> . |
|---|-----------------------|--|--|
| 314.63                                    | 20                    | 3.42   | 6.04   |
| "   | "                     | 3.45   | 6.09   |
| "   | "                     | 3.40   | 6.00   |
| "   | "                     | 3.41   | 6.02   |
| "   | "                     | 3.43   | 6.05   |
| "   | "                     | 3.40   | 6.00   |
| "   | "                     | 3.36   | 5.93   |
| "   | "                     | 3.40   | 6.00   |
| "   | "                     | 3.40   | 6.00   |
| "   | "                     | 3.50   | 6.18   |
| "   | "                     | 3.38   | 5.96   |
| "   | "                     | 3.40   | 6.00   |

The mean of these determinations gives 6.022<sup>cm<sup>3</sup></sup> of oxygen as the amount dissolved in distilled water at 20° C. and 760<sup>mm</sup>, and while some of the determinations vary considerably from this mean, as a whole they are fairly accordant. This method, moreover, is applicable to carbonated water.

ART. LIV.—*Local Deformation of Strata in Meade County Kansas and Adjoining Territory (Preliminary)\**; by ERASMUS HAWORTH.

WHILE making geological investigations in Meade and adjoining counties in western Kansas during the summer of 1896, the writer found certain conditions which seem to be best explained by the conclusion that a fault of considerable magnitude exists in Meade county, a fault decidedly larger than any other one known in the state, and hence worthy of this preliminary notice.

Kansas occupies a middle position in the great plains between the Rocky Mountain system and the Mississippi River. Its eastern limit is about 200 miles west of the river, and its western border—400 miles away—is a like distance east of the easternmost part of the Rockies. Nowhere in the state has there yet been found marks of vigorous orographic movements, although in many localities slight faults and gentle flexures are known.

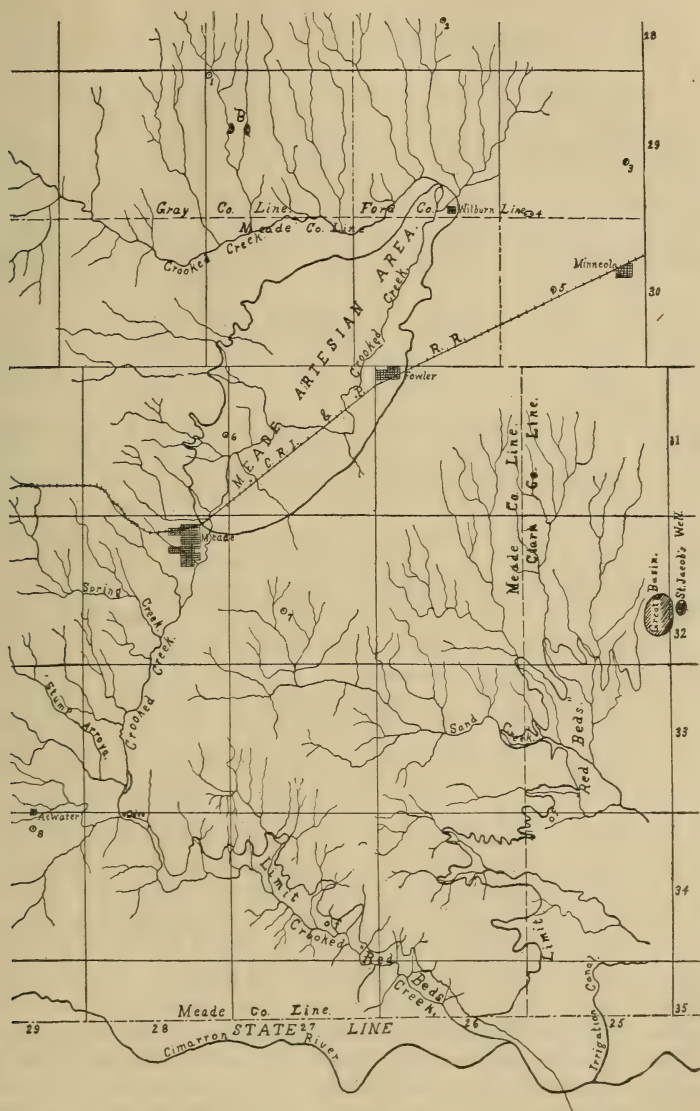
The general conditions of deformation in the plains to the north and south of Kansas are about the same as within the state, while both east and west such conditions are more strongly marked. The movements to the east and southeast in Missouri which produced the Ozark uplift, and a similar though more pronounced uplift in Arkansas, extended in a milder form to eastern Kansas, as is abundantly shown by the numerous fissures and faults of slight dislocation and the gentle flexures so common to that part of the state. To the west in eastern Colorado, as the Rocky mountains are approached, disturbances are much more common and more marked in degree, as is well known to geologists generally.

(a). *Geographic evidences of deformation.*

By referring to the accompanying map the general geography of the district under consideration may be understood. Crooked Creek, the stream most affected by the fault, rises in the extreme eastern part of Haskell county and flows almost due east to near the little village of Wilburn. Here it suddenly turns to the southwest, making an angle of about forty-five degrees with itself, to about twelve miles south of Meade, where it veers southeastward to its junction with the Cimarron river. The bluff lines along Crooked Creek are quite interesting in character, particularly below Meade. Throughout the portion

\* Published with consent of the Director of the United States Geological Survey.





Map of Meade County, Kansas. Showing location of the Meade artesian valley and drainage of contiguous areas, largely copied from U. S. topographic maps, by Erasmus Haworth.

of its course where it flows east the bluffs on either side of the creek are not especially different from the ordinary. Tributaries from the north are most numerous but quite a number are found entering the creek from the south in the north-western part of Meade county. Farther east, opposite the artesian area, no tributaries of any consequence are found on the south, while arroyas of greater or less size are found every mile or two on the north. For twenty miles below the sharp angle at Wilburn scarcely a tributary as much as two miles in length enters from the east, while the drainage streams flowing south-east to the Cimarron rise almost on the verge of the eastern bluffs of Crooked Creek. Throughout this distance many tributaries enter from the west, the most important being Spring Creek, about twelve miles long, and Stump arroya, nearly as long.

The general character of the uplands is that of a broad plain inclined to the southeast about ten feet to the mile. The various drainage channels are cut down into this plain, generally producing abrupt bluffs on each side. From Wilburn to Meade, however, the bluffs of Crooked Creek are far apart, with the whole of the artesian area between. Below Meade the bluffs on the east side of the creek are high and abrupt, often being almost precipitous in character. They have a decidedly new appearance, as though the erosion which produced them was very modern. Almost none of the rounded forms of old age are to be found, but the angular points and steep walls of recent formation are everywhere present. On the western side there is a gently sloping plain stretching from the creek to from one to five miles away, producing an appearance scarcely duplicated within the state. The general upland plain from eight to twelve miles to the west of Crooked Creek both physiographically and geologically corresponds with the plain on the east of the creek, which approaches to within less than a quarter of a mile of the creek valley. The general appearance from Meade southward is that of a fault with the western wall dropped and Crooked Creek occupying a position over the fault line. Northward the whole artesian valley seems to have been dropped downwards, leaving an abrupt wall on the west, and a more gentle wall on the east. Standing anywhere in the valley one can see the wall all around him. On the west it is considerably over a hundred feet in height, while to the east it is some less, but still very perceptible. We have here a valley occupying almost twenty square miles which is so different from anything else known in this part of the country that it is exceedingly difficult to explain its origin by any system of erosion. The peculiar position of the creek is likewise hard to explain by any ordinary conditions of erosion. The sharp angle at

Wilburn and the southwestern direction for nearly twenty miles across a plain sloping to the southeast are certainly very remarkable, and probably have a cause different from that which ordinarily determines the location and direction of a stream. But if in post-Tertiary times a triangular area equaling in size and position the present artesian area could have dropped a hundred feet or more with a single fault line extending southward to beyond the limits of Kansas, thereby changing the direction of Crooked Creek into the present channel below Wilburn, the general physiographic conditions could easily be accounted for.

It should be added that there is a chain of wet-weather lakes reaching eastward from Wilburn to the north of Minneola which may represent the former channel of the eastward extension of Crooked Creek. An examination of the country lends more color to this view than can be gained from the U. S. topographic sheets, for the twenty-foot contour lines often fail to represent physiographic conditions of great importance in such studies as these.

Other lesser disturbances have occurred in this locality. About one and a half miles south of Meade, on the eastern bluff of Crooked Creek a sink hole a hundred feet across, thirty or more feet deep, and almost circular in form was formed, tradition has it, less than thirty years ago. It is reported that a trail formerly passed directly over the sink hole. A very strong brine now fills the bottom of the hole, the salt probably having been obtained from the adjoining Tertiary clays, which are perceptibly saline. It would seem that this is an ordinary sink hole caused by portions of the sub-surface materials having been carried away by solution.

A few miles to the southeast of this area in western Clark county other indications of local disturbances are found. A broad and level valley more than a mile across and nearly circular in outline seems to have been dropped vertically for about a hundred and fifty feet. This is locally called the great basin. On the east of it a hundred yards is a similar valley a fourth as large, which likewise seems to have been dropped a like distance. In the northern part of this latter valley a sink hole about seventy-five feet across now holds fresh water with a maximum depth of twenty-seven feet. This is locally called St. Jacob's well, and is so marked on the U. S. topographic sheets.

These two areas are so large that it is difficult to understand how they can be classed as ordinary sink holes, as the Meade salt well may be. Their origin should be looked upon as due to some greater movements, possibly similar in character to that which produced the artesian valley near Meade, although no connecting fault has yet been located.



(b.) *Geologic evidences of deformation.*

The general geology of this part of the state is now pretty well understood. Excepting a small area in the southeast the whole surface is covered with the Tertiary sands and clays. In the northern part of the area these rest directly on the Benton limestone and shales, which gradually thin out and entirely disappear in the northern part of Meade county. Below the Benton lies the Dakota, which also thins southward and disappears near the middle of the county. As these formations are usually entirely covered by the Tertiary, we know of their presence only by well records, therefore their exact southern limits cannot well be stated. South of this the Tertiary rests directly on the "Red-Beds," as is abundantly shown by many exposures in the vicinity of Englewood and along Crooked Creek, and by well records on the plains east of Crooked Creek.

Along the northern side of Crooked Creek, in township 29 south, ranges 27 and 28 west, the Benton is occasionally exposed along the arroyas, area marked B on map, and is often reached in well drilling. The same condition obtains to the east and northeast of Minneola. Each of the wells, numbers 1, 2 and 3 on map, reached the Benton, and 2 and 3 passed through it into the Dakota. At Mr. Hall's place, well number 4, three miles east of Wilburn, two wells were started at his house, each of which struck the Dakota at 60 feet, the Benton not reaching this far south. About 200 yards to the west of these, two other wells were drilled to a depth of over 90 feet without reaching the Dakota. Here the surface slopes gently to the west, and the Dakota is known to have a general rise to the west of about ten feet to the mile, so the Dakota should have been reached at about 55 feet. We therefore have the fault line located somewhere between these two groups of wells, all of which are in the southwest quarter, section 32, township 29 south, 25 west. About a half mile north of the C. R. I. & P. railroad and a little southeast of the Hall wells, another well—number 5—reached the Dakota. To the west of these wells, in the vicinity of Wilburn and Fowler, many wells are deep enough to have reached the Dakota did it exist in an undisturbed position where it should be, as best we can judge from its exposures farther northeast, and in the localities just given, where it is reached by the wells. Farther west both Benton and Dakota were reached by a well at Santa Fe, and the Dakota comes to the surface near the western line of the state.

The artesian valley is interesting in this connection. Many wells have been carried to a depth of 200 feet or more without

reaching the Dakota, and the one of Mr. Cooper, section 13, township 31 north, 28 west, reached a total depth of 250 feet and found no Dakota, which is at least 200 feet below where it should be found had it not been disturbed. The artesian water is found at depths varying from 50 to 250 feet, and under such varying conditions that it implies a filling in of the valley, producing even greater irregularities than is common to the Tertiary of adjoining areas.

Passing southward along Crooked Creek the first appearance of the "Red Beds" is on the east bank about three miles above the present location of Odee P. O.—not the place by a few miles as marked on the U. S. topographic sheets. They are again found on the east bank at Odee, and are exposed almost all the way below this point to the Cimarron, usually with the Tertiary capping the tops of the bluffs. Near Atwater, on the plain west of Crooked Creek, Mr. Ivers has recently drilled a well on section 3, township 34 south, 29 west, which was carried to the unusual depth of 288 feet without reaching the "Red Beds," while from their position a short distance east they should have been reached at about 100 feet. It is an important fact that no "Red Beds" can be found at or near the surface on the west side of the creek, while from here down to the Cimarron, and down the Cimarron to Englewood, they rise in bluffs along the east side to heights more than 100 feet. This condition obtains south of the state line, and after the western bluffs attain a considerable height. Passing on down the Cimarron, the "Red Beds" bluffs are markedly prominent on the north side with no traces of them on the south until a point in Beaver county, Oklahoma, is reached almost opposite the mouth of Col. Perry's irrigation canal—see map—when they appear on the south side and suddenly form as prominent bluffs as any on the north. By referring to the map it will be seen that this line is in range with the direction of Crooked Creek.

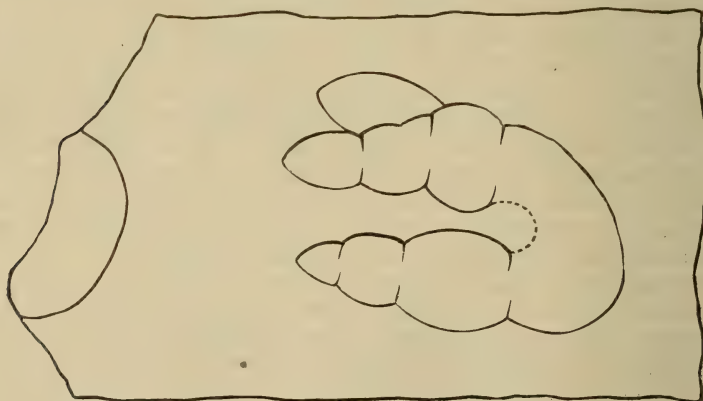
Summing the whole matter up, it would seem that the peculiar and apparently irregular conditions of physiography and geologic structure in the area under consideration can only be explained by assuming the existence of deformations principally due to a dislocation fault approximating in position the present location of Crooked Creek below Wilburn, a fault with the western side dropped at least about 200 feet.

Geological Department, University of Kansas,  
Lawrence, Oct. 5th, 1896.

ART. LV.—*Amphibian Footprints from the Devonian;*  
by O. C. MARSH.

No evidence of vertebrate life higher than that of Fishes has hitherto been found in the Devonian formation. In the Carboniferous next above, however, many characteristic remains of Amphibians have long been known, proving that this form of vertebrate life was comparatively abundant at that period.

The Yale Museum has recently secured from the upper Devonian strata of western Pennsylvania, a specimen that shows one vertebrate footprint in fair preservation, and with it part of another of the same series. These impressions are of much interest, both on account of their geological age and the size and character of the footprints themselves. The one best preserved is nearly four inches in length, two and a quarter in width, and was apparently made by a left hind foot. On the inner side in front of the heel, a portion of the margin is split off, and this may have contained the imprint of another toe. The other footprint was a short distance in front, but only the posterior portion is now preserved in the present specimen. It is probably the imprint of the fore foot. The figure shown below represents these two impressions.



Outline of Devonian footprints (*Thinopus antiquus*, Marsh).  
One-half natural size.

The specimen here figured was recently found in the town of Pleasant, one mile south of the Allegheny River, Warren County, Pennsylvania, by Dr. Charles E. Beecher, who presented it to the Yale Museum, and also furnished the present information in regard to its geological position.

The geological horizon is near the top of the Chemung, in the upper Devonian. In the same beds are ripple marks, mud cracks, and impressions of rain drops, indicating shallow



water and shore deposits. Land plants are found in the same general horizon. Marine mollusks also occur, and one characteristic form (*Nuculana*) is preserved in the footprint slab.

This specimen, although not important in itself, is worthy of record as indicating the existence of an air-breathing vertebrate, apparently amphibian, in the Devonian, and also as offering an incentive to further exploration in the same horizon.

Yale University, New Haven, Conn., October 16, 1896.

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ART. LVI.—*The Geology of Block Island (Continued)*; by  
O. C. MARSH.

THE short article with the above title, in the last number of this Journal (pp. 295–298), was essentially a preliminary notice in the discussion of a much larger question relating to the presence or absence of the Jurassic formation on the Atlantic coast, a subject that I have been investigating for several years. The main object was to record my own observations at a few points, with the conclusions suggested, leaving a discussion of the whole subject for another occasion.

As my conclusions were so different from any that had been expressed by previous writers, I thought it best to present them based on my own investigations, rather than to attempt a discussion of the views of all others. To have cited the entire literature of the subject, extending over a century, would have taken the greater part of the limited space then at my command, and seemed hardly necessary.

Since my article was published, I have had further opportunity to follow out the investigation in several directions, and hope soon to place these results, also, on record. I may say here, however, that an examination of both the Raritan and Staten Island clay deposits has supplied two links in a chain of evidence, that I had not before known from personal observation. This chain now extends from the Potomac River to Martha's Vineyard, along the natural line of the Jurassic horizon, and indicates the Jurassic age of this series of strata beyond reasonable doubt.

Many and various opinions have been expressed as to the geological age of this series of strata, especially of the clays east of the Hudson River which are here under consideration.

The brilliant, variegated cliffs of Gay Head seem to have first attracted the attention of both mariners and geologists, and descriptions of their geological features began more than one hundred years ago. In 1786, Samuel West and William Baylies together explored Gay Head, and separately recorded what they saw, in vol. ii, *Memoirs of the American Academy of Arts and Sciences*, 1793. They discovered the bones of

whales, sharks' teeth, petrified shells, and fossil wood, and agreed that the cliffs were due to volcanic action, an opinion still maintained by the existing Gay Head Indians.

In 1824, John Finch, in discussing the "Tertiary Formations in America" (this Journal, vol. vii, pp. 31-43, 1825), stated his opinion that the Gay Head clays, as well as some on Long Island, and at Amboy, New Jersey, and still others farther south, were of the same age as the Alum Bay clays (Oligocene) on the Isle of Wight. E. Hitchcock, in the same year, and in the same volume of this Journal, pp. 240-248, regarded the Martha's Vineyard clays as the equivalents of the Plastic clay (Eocene) of Europe. Hitchcock, again in 1832, as state geologist, mapped and described this region as Tertiary, and in his report published in 1833 gave figures and descriptions of Gay Head fossils. The final report, 1841, contained a more complete description, and the Eocene age of the clays of Martha's Vineyard is still maintained. Lyell, in 1844 (Proc. Geol. Soc. London, vol. iv, and this Journal, vol. xlii, pp. 318-320), made a study of Gay Head and other localities on the island, and regarded the cliffs as of Miocene age. E. Desor and E. C. Cabot, in 1849, announced that certain clays on Nantucket were Miocene, and the equivalents of those on Gay Head (Quart. Jour. Geol. Soc. London, vol. v, pp. 340-344). W. Stimpson, in 1860, pronounced the strata at Gay Head, Cretaceous (this Journal, vol. xxix, p. 145), but subsequently withdrew that opinion in favor of their Tertiary age.

In more recent times, also, this opinion still prevailed, and even the later age of Post-pliocene or Quaternary was, in 1885, assigned to the Gay Head clays by F. J. H. Merrill (Trans. N. Y. Acad. Sci., vol. iv, p. 79). Shaler, whose valuable memoirs on Martha's Vineyard and Nantucket (1888-'89) I quoted in my previous article, still regarded the basal clays of both islands as Tertiary or later. In another paper (Bull. Mus. Comp. Zool., vol. xvi, p. 89, 1889), he discussed the discovery of marine Cretaceous fossils in the drift of Martha's Vineyard. In a still later paper (Bull. Geol. Soc. America, vol. i, pp. 443-452, 1890), he considered the lower portion of Gay Head, Cretaceous, and the middle, Tertiary. He adds that A. F. Foerste observed, on Block Island, beds probably of the same age as the Tertiary at Gay Head.

A study of the fossil plants of Gay Head, in 1890, by David White, indicated that some of the clays of Martha's Vineyard were Mesozoic, and they were pronounced by him Cretaceous, and probably middle Cretaceous (this Journal, vol. xxxix, p. 99). To this important paper, I am indebted for various references. These researches were made under the direction of L. F. Ward, whose comprehensive work on the Potomac formation (U. S. Geol. Surv., 15th Ann. Rep., 1895) is invaluable to all interested in that horizon.

Block Island, owing probably to its diminutive size and isolated position, has attracted but little attention from geologists, although situated as it is between Long Island and Martha's Vineyard, it is an intermediate station of considerable importance. The first notice of its geological features is apparently that of C. T. Jackson, in 1840, in his report as state geologist of Rhode Island, pp. 111-120. He carefully described the Block Island clays, and considered them of Tertiary age, although he was unable to find in them any remains of marine shells.

The next notice of importance is by W. Upham, in 1879, who regarded nearly all the Block Island clays as of glacial origin. Some of them appeared to be older, but he makes no statement as to their age. After discussing Long Island, he sums up the effects of glacial action, as follows:—

“Excepting the pre-glacial deposits which have been mentioned, and a small area of gneiss and hornblende schist at Long Island City and Astoria, the whole of Long Island, Block Island, Martha's Vineyard, Nantucket, the Elizabeth Islands, and the peninsula of Cape Cod, consist of drift deposits which owe their accumulation, as has been here shown, to the action of the ice-sheet and its rivers in amassing them at its termination” (this *Journal*, vol. xviii, pp. 91, 92, and 207).

This general opinion has widely prevailed, and I referred to it in my previous article. Another paper on Block Island, which I have not seen, is by Merrill, 1895 (*Trans. N. Y. Acad. Sci.*, vol. xv, pp. 16-19).

The literature relating to the geology of Long Island is quite extensive, but cannot be cited here. The basal clays of this island have been variously regarded as Glacial, Tertiary, and Cretaceous, but not older. The most important of the early descriptions is by Mather, in his *Report on the Geology of the First District of New York*, 1843. One of the later papers of special interest is by Merrill, *On the Geology of Long Island*, 1885 (*Ann. N. Y. Acad. Sci.*, vol. iii, pp. 341-364).

Newberry, in 1874, pronounced the plants from Lloyd's Neck similar to those from the lower Cretaceous of the West (*Proc. N. Y. Lyceum Nat. Hist.*, vol. ii, p. 127). This reference of the fossil plants of Long Island to the Cretaceous has since been followed by many authorities.

One of the latest writers on this subject is A. Hollick, who has kindly sent me, at my request, a number of his papers which I had not before seen.

The mutual relations of all the series of strata here considered, which I regard as Jurassic, I hope to discuss in the next number of this *Journal*.

Yale University, New Haven, Conn., October 21, 1896.



## SCIENTIFIC INTELLIGENCE.

## I. CHEMISTRY AND PHYSICS.

1. *Lucium, a supposed new element.*—M. P. BARRIÈRE, in investigating monazite sand, has separated what he believes to be a new element; to this he has given the name *lucium*. Its chemical properties, compared with those of related elements, are stated to be as follows:

"The salts of cerium, lanthanum, and didymium form with sodium sulphate insoluble double salts; lucium does not. Thorium and zirconium form insoluble double salts with potassium sulphate; this is not the case with lucium. Yttrium, ytterbium, and erbium are not precipitable by sodium thiosulphate, whilst lucium chloride is precipitable. From glucinium lucium differs, as its salts are precipitable by oxalic acid.

According to the results obtained by Prof. Schützenberger, confirmed by those of Cleve, Fresenius, and Lecoq de Boisbaudran, lucium dissolves in sulphuric, nitric, or acetic acid, forming salts either white or slightly tinted with rose-colour. All its salts are soluble in water, forming limpid, colourless solutions.

The spectral rays of lucium are special, and only approximate slightly to those of erbium. Erbium oxide, on ignition, appears of a very pure rose-colour, and its nitrate is red. On the contrary, lucium oxide is white, slightly greyish, and its nitrate is white. The aqueous solutions of the erbium salts are red or rose-colour; those of lucium, even if containing 15 or 20 per cent of the salt, are almost colourless.

The atomic weight of lucium is calculated as = 104, whilst—

|                |        |
|----------------|--------|
| Thorium.....   | = 233  |
| Yttrium.....   | = 89   |
| Ytterbium..... | = 173  |
| Scandium.....  | = 44.5 |
| Cerium.....    | = 140  |
| Lanthanum..... | = 156  |
| Erbium.....    | = 166  |
| Zirconium..... | = 90   |
| Samarium.....  | = 150  |
| Glucinium..... | = 9    |

Hence the authorities cited regard lucium as a new, distinct elementary body."—*Chem. News*, Sept. 25, 1896.

2. *On the occurrence of gallium in the clay-ironstone of the Cleveland district, Yorkshire.*—In the course of an investigation of flame spectra at high temperatures, W. N. HARTLEY and HUGH RAMAGE have examined the flames from the converters of the basic Bessemer process at Middlesbrough-on-Tees. A large number of photographs were taken, which are stated to have been remarkably fine in definition, and extending from the less refran-

gible limit of the red rays to the ultra-violet above wave-length 3240. The authors have identified all the lines and bands represented, and by this means have proved the presence of the rare element *gallium* in the Bessemer metal and in the roasted ore from which it was extracted. Careful analyses showed that the gallium was concentrated in the iron. The lines 4171.6 and 4032.7 (on Rowland's scale) were repeatedly observed in the spectrum of the Bessemer flame, again in that of the "mixer" metal and in the residue or precipitates separated from it, and finally in that of the residues obtained upon treatment of the roasted Cleveland ore itself.—*Proc. Roy. Soc.*, lx, 35.

3. *Flame temperatures.*—W. J. WAGGENER has made a detailed study of the Bunsen flame with the aid of thermo-couples of platinum and a 10-per-cent platinum-rhodium alloy. In most cases the wires of the couple were taken straight through the flame, with the junction nearest the center. The conductivity and the E.M.F. of the flame were found to be without influence upon the galvanometer currents. But in every case the wires had to be quickly removed from the flame after taking a reading, as their thermal E.M.F.'s suffered a gradual alteration in the flame. In the outer mantle of the flame the temperatures indicated by most of the thermo-couples ranged from 1500° to 1700° C., according to the height above the base of the flame. The hottest point was at a height of 2<sup>cm</sup>; the total height of the flame being 10<sup>cm</sup>. The coldest part of the flame, about 1400° C., was found near the top of the blue inner mantle. In all the observations, the conduction of heat along the wire reduced the temperature of the junction and vitiated the results. The hottest part of the flame, in the outer mantle, was 1724° C., as indicated by the thinnest of the wires (0.05<sup>mm</sup> diameter). Taking the increase of temperature with the reduction of diameter, and plotting a curve, the latter is found to cut the axis of no thickness at a point corresponding to about 1770°, which may therefore be taken as very approximately the true value of the highest temperature of the Bunsen flame.—*Wied. Ann.*, lviii, 579; *Proc. Phys. Soc.*, xiv, 315.

4. *Liquefaction of Helium.*—K. OLSZEWSKI having been presented by Professor Ramsay with 140<sup>ccm</sup> of helium, endeavored to liquefy it with the apparatus which he has used in his researches on oxygen and hydrogen.\* The results were negative. Helium appears to be more permanent than hydrogen. The quantity of gas employed, however, was too small to afford definite conclusions. Olszewski believes that his experimental results show the single atom constitution of helium. The relation of this one atom constitution to the difficulty of liquefaction is even more marked in the case of helium than in that of argon. In consequence of its permanence of constitution helium affords a valuable means of determining temperatures beyond the boiling

\* Further details in regard to these experiments were given in the October number, p. 301.

point of hydrogen. The hydrogen thermometer can not be used beyond  $-194^{\circ}$ . The helium thermometer can afford useful service if it can be shown by further study to be reliable at the temperature  $-234.5^{\circ}$ , which is the boiling point of hydrogen.—*Ann. der Physik und Chemie*, No. 9, 1896, pp. 184-92. J. T.

5. *Photometry of the ultra violet portion of the Solar Spectrum.*—HERMAN TH. SIMON refers to the various methods which have been employed in the less refrangible portion of the spectrum, and describes an apparatus which serves for the photometric study of the spectrum from the red to the ultra violet. The measurement of light intensity with the author's method reached an exactness of  $\frac{1}{2000}$ : and the qualitative determination of the ultra violet absorption spectrum of a nitrate of potash solution gave a mean error of each determination of only 1.3 per cent.

The method consists of the use of a slotted revolving disc, by means of which the light of an arc lamp is suitably weakened, in order that comparison can be made with other sources of light, either by the eye method or by comparison of the intensity of photographic negatives.—*Ann. der Physik und Chemie*, No. 9, 1896, pp. 91-115. J. T.

6. *Electrical Indices of Refraction.*—P. DRUDE has continued his work on the electrical indices of refraction of water and aqueous solutions. The method consists in measuring the variation in length of electrical waves along wires before and after a definite length of the wires is immersed in the various solutions. The results were as follows:

For oscillations  $4 \times 10^8$  per second, the square of the electrical index of refraction of water for  $17^{\circ}$  C. is  $n^2 = 81.67$ .

For oscillations  $1.5 \times 10^8$  per second,  $n^2 = 80.60$ , for oscillations  $8 \times 10^8$   $n^2 = 83.6$ . Water shows normal dispersion within the limits of the rates of oscillation.

Between  $0^{\circ}$  and  $26^{\circ}$  changes in  $n^2$  are proportional to the temperature.

With cane sugar solutions the electrical refractive indices are sensibly smaller than with pure water. The solutions show anomalous electric absorption and anomalous electric dispersion, and so much the more the higher the concentration. A 65-per cent solution absorbs the waves like an electrolytically conducting aqueous solution of the conductivity  $k = 3 \times 10^{-7}$ .—*Ann. der Physik und Chemie*, No. 9, 1896, pp. 17-62. J. T.

7. *Electrical Oscillations in a conducting sphere capable of polarization.*—RYDBERG, KAYSER and RUNGE have stated that there exist periodic relations between the spectral lines of different metals and the constitution of such metals. If  $N$  denotes the period of swing of lines belonging to the same series,  $N = A - B n^2 - C n^{-4}$ , in which  $A B C$  are constants,— $n$  the position number of lines in the series;  $A B C$  have different values from series to series. In every spectrum there exists a principal series, with easily producible and easily reversible double lines, or in other words, two main series of simple lines which give oppor-



tunity for doublets. Only in the case of lithium exist simple lines. The breadth of the doublets, that is the difference between the powers of the position number  $n$ , increase as the fourth power of  $n$ . The number  $n = 3$  in the case of sodium indicates the yellow D lines. With Li the red line, with K, Rb red double lines, and with Cs an ultra red double line, the higher values of  $n = 4.5$  etc. include the closely crowded together lines of the ultra violet portion of the spectrum. FRANZ KOLÁČEK has endeavored to find analogous series in the case of the electromagnetic swinging of a conducting sphere, which is capable of polarization, in a dielectrically polarizable ether. His mathematical analysis conducts him to series which are analogous to those treated by Kayser and Runge.—*Ann. der Physik und Chemie*, No. 6, 1896, pp. 271–310. J. T.

8. *A Magnetic Detector of Electrical Waves*.—E. RUTHERFORD states that the effect of Leyden jar discharges in partially demagnetizing them affords a simple and convenient method of detecting and comparing currents of great rapidity of alternation. The partial demagnetization of a collection of fine steel wires, insulated from each other, over which is wound a small solenoid in series with the receiving wires, was found to be a sensitive means of detecting electrical waves at long distances from the vibrator. A small but quite marked effect was obtained at a distance of half a mile from the vibrator.—*Nature*, July 9, 1896, p. 239. J. T.

9. *Discharge of an electrified body by means of the Tesla Spark*.—FREDERICK J. SMITH states that a high frequency spark between two blunt points one inch apart in air acts like the Röntgen rays in dispelling electric charges, of either sign.—*Nature*, July 30, p. 296. J. T.

10. *On the nature of the Röntgen rays*; by J. J. THOMSON.\*—The discovery at the end of last year by Prof. Röntgen of a new kind of radiation from a highly exhausted tube through which an electric discharge is passing, has aroused an amount of interest unprecedented in the history of physical science. The effects produced *inside* such a tube by the kathode rays, the bright phosphorescence of the glass, the shadows thrown by opaque objects, the deflection of the rays by a magnet, have, thanks to the researches of Crookes and Goldstein, long been familiar to us, but it is only recently that the remarkable effects which occur outside such a tube have been discovered. In 1893, Lenard, using a tube provided with a window made of a very thin plate of aluminium, found that a screen impregnated with a solution of a phosphorescent substance became luminous if placed outside the tube in the prolongation of the line from the kathode through the aluminium window. He also found that photographic plates placed outside the tube in this line were affected, and electrified bodies were discharged; he also obtained by these rays photographs through plates of aluminium or quartz. He found that

\* From an address delivered before Section A of the British Association at the Liverpool meeting, *Nature*, vol. liv, p. 472 *et seq.*

the rays were affected by a magnet, and regarded them as the prolongations of the kathode rays. This discovery was at the end of last year followed by that of Röntgen, who found that the region round the discharge tube is traversed by rays which affect a photographic plate after passing through substances such as aluminium or cardboard, which are opaque to ordinary light; which pass from one substance to another, without any refraction, and with but little regular reflection; and which are not affected by a magnet. We may, I think, for the purposes of discussion, conveniently divide the rays occurring in or near a vacuum tube traversed by an electric current into three classes, without thereby implying that they are necessarily distinctly different in physical character. We have (1) the kathode rays inside the tube, which are deflected by a magnet; (2) the Lenard rays outside the tube, which are also deflected by a magnet; and (3) the Röntgen rays, which are not, as far as is known, deflected by a magnet. Two views are held as to the nature of the kathode rays; one view is, that they are particles of gas carrying charges of negative electricity, and moving with great velocities which they have acquired as they traveled through the intense electric field which exists in the neighborhood of the negative electrode. The phosphorescence of the glass is on this view produced by the impact of these rapidly moving charged particles, though whether it is produced by the mechanical violence of the impact, or whether it is due to an electro-magnetic impulse produced by the sudden reversal of the velocity of the negatively charged particle—whether, in fact, it is due to mechanical or electrical causes, is an open question. This view of the constitution of the kathode rays explains in a simple way the deflection of those rays in a magnetic field, and it has lately received strong confirmation from the results of an experiment made by Perrin. Perrin placed inside the exhausted tube a cylindrical metal vessel with a small hole in it, and connected this cylinder with the leaves of a gold-leaf electroscope. The kathode rays could, by means of a magnet, be guided so as either to pass into the cylinder through the aperture, or turned quite away from it. Perrin found that when the kathode-rays passed into the cylinder the gold leaf of the electroscope diverged, and had a negative charge, showing that the bundle of kathode rays enclosed by the cylinder had a charge of negative electricity. Crookes had many years ago exposed a disc connected with a gold-leaf electroscope to the bombardment of the kathode rays, and found that the disc received a slight *positive* charge; with this arrangement, however, the charged particles had to give up their charges to the disc if the gold leaves of the electroscope were to be affected, and we know that it is extremely difficult, if not impossible, to get electricity out of a charged gas merely by bringing the gas in contact with a metal. Lord Kelvin's electric strainers are an example of this. It is a feature of Perrin's experiment that since it acts by induction, the indications of the

electroscope are independent of the communication of the charges of electricity from the gas to the cylinder, and since the kathode rays fall on the inside of the cylinder, the electroscope would not be affected, even if there were such an effect as is produced when ultra-violet light falls upon the surface of an electro-negative metal when the metal acquires a positive charge. Since any such process cannot affect the total amount of electricity inside the cylinder, it will not affect the gold leaves of the electroscope; in fact, Perrin's experiments prove that the kathode rays carry a charge of negative electricity.

The other view held as to the constitution of the kathode rays is that they are waves in the ether. It would seem difficult to account for the result of Perrin's experiment on this view, and also I think very difficult to account for the magnetic deflection of the rays. Let us take the case of a uniform magnetic field: the experiments which have been made on the magnetic deflection of these rays seem to make it clear that in a magnetic field which is sensibly uniform, the path of these rays is curved; now if these rays were due to ether waves, the curvature of the path would show that the velocity of propagation of these waves varied from point to point of the path. That is, the velocity of propagation of these waves is not only affected by the magnetic field, it is affected differently at different parts of the field. But in a uniform field what is there to differentiate one part from another, so as to account for the variability of the velocity of wave propagation in such a field? The curvature of the path in a uniform field could not be accounted for by supposing that the velocity of this wave motion depended on the strength of the magnetic field, or that the magnetic field, by distorting the shape of the boundary of the negative dark space, changed the direction of the wave front, and so produced a deflection of the rays. The chief reason for supposing that the kathode rays are a species of wave motion is afforded by Lenard's discovery, that when the kathode rays in a vacuum tube fall on a thin aluminium window in the tube, rays having similar properties are observed on the side of the window outside the tube; this is readily explained on the hypothesis that the rays are a species of wave motion to which the window is partially transparent, while it is not very likely that particles of the gas in the tube could force their way through a piece of metal. This discovery of Lenard's does not, however, seem to me incompatible with the view that the kathode rays are due to negatively charged particles moving with high velocities. The space outside Lenard's tube must have been traversed by Röntgen rays; these would put the surrounding gas in a state in which a current would be readily started in the gas if any electromotive force acted upon it. Now, though the metal window in Lenard's experiments was connected with the earth, and would, therefore, screen off from the outside of the tube any effect arising from slow electrostatic changes in the tube, it does not follow that it would be able to screen off the



electrostatic effect of charged particles moving to and from the tube with very great rapidity. For in order to screen off electrostatic effects, there must be a definite distribution of electrification over the screen; changes in this distribution, however, take a finite time, which depends upon the dimensions of the screen and the electrical conductivity of the material of which it is made. If the electrical changes in the tube take place at above a certain rate, the distribution of electricity on the screen will not have time to adjust itself, and the screen will cease to shield off all electrostatic effects. Thus the very rapid electrical changes which would take place if rapidly moving charged bodies were striking against the window, might give rise to electromotive forces in the region outside the window, and produce convection currents in the gas which has been made a conductor by the Röntgen rays. The Lenard rays would thus be analogous in character to the kathode rays, both being convective currents of electricity. Though there are some points in the behavior of these Lenard rays which do not admit of a very ready explanation from this point of view, yet the difficulties in its way seem to me considerably less than that of supposing that a wave in the ether can change its velocity when moving from point to point in a uniform magnetic field.

I now pass on to the consideration of the Röntgen rays. We are not yet acquainted with any crucial experiment which shows unmistakably that these rays are waves of transverse vibration in the ether, or that they are waves of normal vibration, or indeed that they are vibrations at all. As a working hypothesis, however, it may be worth while considering the question whether there is any property known to be possessed by these rays which is not possessed by some form or other of light. The many forms of light have in the last few months received a noteworthy addition by the discovery of M. Becquerel of an invisible radiation, possessing many of the properties of the Röntgen rays, which is emitted by many fluorescent substances, and to an especially marked extent by the uranium salts. By means of this radiation, which, since it can be polarized, is unquestionably light, photographs through opaque substances similar to, though not so beautiful as, those obtained by means of Röntgen rays, can be taken, and, like the Röntgen rays, they cause an electrified body on which they shine to lose its charge, whether this be positive or negative.

The two respects in which the Röntgen rays differ from light is in the absence of refraction and perhaps of polarization. Let us consider the absence of refraction first. We know cases in which special rays of the spectrum pass from one substance to another without refraction; for example, Kundt showed that gold, silver, copper allow some rays to pass through them without bending, while other rays are bent in the wrong direction. Pflüger has lately found that the same is true for some of the aniline dyes when in a solid form. In addition to this, the theory

of dispersion of light shows that there will be no bending when the frequency of the vibration is very great. I have here a curve taken from a paper by Helmholtz, which shows the relation between the refractive index and the frequency of vibration for a substance whose molecules have a natural period of vibration, and one only; the frequency of this vibration is represented by  $\cdot OK$  in the diagram. The refractive index increases with the frequency of the light until the latter is equal to the frequency of the natural vibration of the substance; the refractive index then diminishes, becomes less than unity, and finally approaches unity, and is practically equal to it when the frequency of the light greatly exceeds that of the natural vibration of the molecule. Helmholtz's results are obtained on the supposition that a molecule of the refracting substance consists of a pair of oppositely electrified atoms, and that the specific inductive capacity of the medium consists of two parts, one due to the ether, the other to the setting of the molecules along the lines of electric force.

Starting from this supposition, we can easily see without mathematical analysis that the relation between the refractive index and the frequency must be of the kind indicated by the curve. Let us suppose that an electromotive force of given amplitude acts on this mixture of molecules and ether, and let us start with the frequency of the external electromotive force less than that of the free vibrations of the molecules: as the period of the force approaches that of the molecules, the effect of the force in pulling the molecules into line will increase; thus the specific inductive capacity, and therefore the refractive index increases with the frequency of the external force; the effect of the force on the orientation of the molecules will be greatest when the period of the force coincides with that of the molecules. As long as the frequency of the force is less than that of the molecules, the external field tends to make the molecules set so as to increase the specific inductive capacity of the mixture; as soon, however, as the frequency of the force exceeds that of the molecules, the molecules, if there are no viscous forces, will all topple over and point so as to make the part of the specific inductive capacity due to the molecules of opposite sign to that due to the ether. Thus, for frequencies greater than that of the molecules, the specific inductive capacity will be less than unity. When the frequency of the force only slightly exceeds that of the molecules, the effect of the external field on the molecules is very great, so that if there are a considerable number of molecules, the negative part of the specific inductive capacity due to the molecules may be greater than the positive part due to the ether, so that the specific inductive capacity of the mixture of molecules and ether would be negative; no waves of this period could then travel through the medium, they would be totally reflected from the surface.

As the frequency of the force gets greater and greater, its

effect in making the molecules set will get less and less, but the waves will continue to be totally reflected until the negative part of the specific inductive capacity due to the molecules is just equal to the positive part due to the ether. Here the refractive index of the mixture is zero. As the frequency of the force increases, its effect on the molecules gets less and less, so that the specific inductive capacity continually approaches that due to the ether alone, and practically coincides with it as soon as the frequency of the force is a considerable multiple of that of the molecules. In this case both the specific inductive capacity and the refractive index of the medium are the same as that of the ether, and there is consequently no refraction. Thus the absence of refraction, instead of being in contradiction to the Röntgen rays being a kind of light, is exactly what we should expect if the wave length of the light were exceedingly small.

The other objection to these rays being a kind of light is, that there is no very conclusive evidence of the existence of polarization. Numerous experiments have been made on the difference between the absorption of these rays by a pair of tourmaline plates when their axes are crossed or parallel. Many observers have failed to observe any difference at all between the absorption in the two cases. Prince Galitzine and M. de Karnojitsky, by a kind of cumulative method, have obtained photographs which seem to show that there is a slightly greater absorption when the axes are crossed than there is when the axes are parallel. There can, however, be no question that the effect, if it exists at all, is exceedingly small compared with the corresponding effect for visible light. Analogy, however, leads us to expect that to get polarization effects we must use, in the case of short waves, polarizers of a much finer structure than would be necessary for long ones. Thus a wire bird-cage will polarize long electrical waves, but will have no effect on visible light. Rubens and Du Bois made an instrument which would polarize the infra-red rays by winding very fine wires very close together on a framework; this arrangement, however, was too coarse to polarize visible light. Thus, though the structure of the tourmaline is fine enough to polarize the visible rays, it may be much too coarse to polarize the Röntgen rays if these have exceedingly small wavelengths. As far as our knowledge of these rays extends, I think we may say that though there is no direct evidence that they are a kind of light, there are no properties of the rays which are not possessed by some variety of light.

It is clear that if the Röntgen rays are light rays, their wavelengths are of an entirely different order to those of visible light. It is perhaps worth notice that on the electro-magnetic theory of light we might expect two different types of vibration, if we suppose that the atoms in the molecule of the vibrating substance carried electrical charges. One set of vibrations would be due to the oscillations of the bodies carrying the charges, the other set to the oscillation of the charges on these bodies. The wave-



length of the second set of vibrations would be commensurate with molecular dimensions: Can these vibrations be the Röntgen rays? If so, we should expect them to be damped with such rapidity as to resemble electrical impulses rather than sustained vibrations.

If we turn from the rays themselves to the effect they produce, we find that the rays alter the properties of the substances through which they are passing. This change is most apparent in the effects produced on the electrical properties of the substances. A gas, for example, while transmitting these rays is a conductor of electricity. It retains its conducting properties for some little time after the rays have ceased to pass through it, but Mr. Rutherford and I have lately found that the conductivity is destroyed if a current of electricity is sent through the Röntgenized gas. The gas in this state behaves in this respect like a very dilute solution of an electrolyte. Such a solution would cease to conduct after enough electricity had been sent through it to electrolyze all the molecules of the electrolyte. When a current is passing through a gas exposed to the rays, the current destroys and the rays produce the structure which gives conductivity to the gas; when things have reached a steady state the rate of destruction by the current must equal the rate of production by the rays. The current can thus not exceed a definite value, otherwise more of the conducting gas would be destroyed than is produced.

This explains the very characteristic feature that in the passage of electricity through gases exposed to Röntgen rays, the current, though at first proportional to the electromotive force, soon reaches a value where it is almost constant and independent of the electromotive force, and we get to a state when a tenfold increase in the electromotive force only increases the current by a few per cent. The conductivity under the Röntgen rays varies greatly from one gas to another; the halogens and their gaseous compounds, the compounds of sulphur, and mercury vapor, are among the best conductors. It is worthy of note that those gases which are the best conductors when exposed to the rays are either elements, or compounds of elements, which have in comparison with their valency very high refractive indices.

The conductivity conferred by the rays on a gas is not destroyed by a considerable rise in temperature; it is, for example, not destroyed if it be sucked through metal tubing raised to a red heat. The conductivity is, however, destroyed if the gas is made to bubble through water; it is also destroyed if the gas is forced through a plug of glass wool. This last effect seems to indicate that the structure which confers conductivity on the gas is of a very coarse kind, and we get confirmation of this from the fact that a very thin layer of gas exposed to the Röntgen rays does not conduct nearly so well as a thicker one. I think we have evidence from other sources that electrical conduction is a process that requires a considerable space—a space large enough to enclose a very large number of molecules.

Thus Koller found that the specific resistances of petroleum, turpentine, and distilled water, when determined from experiments made with very thin layers of these substances, was very much larger than when determined from experiments with thicker layers. Even in the case of metals there is evidence that the metal has to be of appreciable size if it is to conduct electricity. The theory of the scattering of light by small particles shows that, if we assume the truth of the electromagnetic theory of light, the effects should be different according as the small particles are insulators or conductors. When the small particles are non-conductors, theory and experiment concur in showing that the direction of complete polarization for the scattered light is at right angles to the direction of the incident light; while if the small particles are conductors, theory indicates that the direction of complete polarization makes an angle of  $60^\circ$  with the incident light. This result is not, however, confirmed by the experiments made by Prof. Threlfall on the scattering of light by very small particles of gold. He found that the gold scattered the light in just the same way as a non-conductor, giving complete polarization at right angles to the incident light. This would seem to indicate that those very finely divided metallic particles no longer acted as conductors. Thus there seems evidence that in the case of conduction through gases, through badly conducting liquids and through metals, electric conduction is a process which requires a very considerable space and aggregations of large numbers of molecules. I have not been able to find any direct experimental evidence as to whether the same is true for electrolytes. Experiments on the resistance of thin layers of electrolytes would be of considerable interest, as according to one widely-accepted view of electrolysis conduction through electrolytes, so far from being effected by aggregations of molecules, takes place by means of the ion, a structure simpler than that of the molecule, so that if this represents the process of electrolytic conduction, there would not seem room for the occurrence of an effect which occurs with every other kind of conduction.

In this building it is only fitting that some reference should be made to the question of the movement of the ether. You are all doubtless acquainted with the heroic attempts made by Prof. Lodge to set the ether in motion, and how successfully the ether resisted them. It seems to be conclusively proved that a solid body in motion does not set in motion the ether at an appreciable distance outside it; so that if the ether is disturbed at all in such a case, the disturbance is not comparable with that produced by a solid moving through an incompressible fluid, but must be more analogous to that which would be produced by the motion through the liquid of a body of very open structure, such as a piece of wire netting, where the motion of the fluid only extends to a distance comparable with the diameter of the wire, and not with that of the piece of netting. There is another class of phenomena relating to the movement of the ether which is, I

think, deserving of consideration, and that is the effect of a varying electro-magnetic field in setting the ether in motion. I do not remember to have seen it pointed out that the electro-magnetic theory of light implicitly assumes that the ether is not set in motion even when acted on by mechanical forces. On the electro-magnetic theory of light such forces do exist, and the equations used are only applicable when the ether is at rest. Consider, for example, the case of a plane electric wave traveling through the ether. We have parallel to the wave-front a varying electric polarization, which on the theory is equivalent to a current; at right-angles to this, and also in the wave-front, we have a magnetic force. Now, when a current flows through a medium in a magnetic field there is a force acting on the medium at right-angles to the plane, which is parallel both to the current and to the magnetic force; there will thus be a mechanical force acting on each unit volume of the ether when transmitting an electric wave, and since this force is at right-angles to the current and to the magnetic force, it will be in the direction in which the wave is propagated. In the electro-magnetic theory of light, however, we assume that this force does not set the ether in motion, as unless we made this assumption we should have to modify our equations, as the electro-magnetic equations are not the same in a moving field as in a field at rest. In fact, a complete discussion of the transmission of electro-magnetic disturbances requires a knowledge of the constitution of the ether which we do not possess. We now assume that the ether is not set in motion by an electro-magnetic wave. If we do not make this assumption, we must introduce into our equation quantities representing the components of the velocity of the ether, and unless we know the constitution of the ether, so as to be able to deduce these velocities from the forces acting on it, there will be in the equations of the electro-magnetic field more unknown quantities than we have equations to determine. It is, therefore, a very essential point in electro-magnetic theory to investigate whether or not there is any motion of the ether in a varying electro-magnetic field. We have at the Cavendish Laboratory, using Prof. Lodge's arrangement of interference fringes, made some experiments to see if we could detect any movement of the ether in the neighborhood of an electric vibrator, using the spark which starts the vibrations as the source of light. The movement of the ether, if it exists, will be oscillatory, and with an undamped vibrator the average velocity would be zero; we used, therefore, a heavily damped vibrator, with which the average velocity might be expected to be finite. The experiments are not complete, but so far the results are entirely negative. We also tried by the same method to see if we could detect any movement of the ether in the neighborhood of a vacuum-tube emitting Röntgen rays, but could not find any trace of such a movement. Prof. Threlfall, who independently tried the same experiment, has, I believe, arrived at the same conclusion.



Unless the ether is immovable under the mechanical forces in a varying electro-magnetic field, there are a multitude of phenomena awaiting discovery. If the ether does move, then the velocity of transmission of electrical vibrations, and therefore of light, will be affected by a steady magnetic field. Such a field, even if containing nothing but ether, will behave towards light like a crystal, and the velocity of propagation will depend upon the direction of the rays. A similar result would also hold in a steady electric field. We may hope that experiments on these and similar points may throw some light on the properties of that medium which is universal, which plays so large a part in our explanation of physical phenomena, and of which we know so little.

11. *Absolute hardness*.—F. AUERBACH shows that the method proposed by Hertz, and worked out by himself, of determining absolute hardness by the optical method, employing lenses and plates of the material in question, and finding what pressure of the one upon the other just brings about disintegration, is capable of great exactness and consistency. Special precautions must be observed to distinguish between the sources of error affecting brittle bodies and those affecting plastic ones. In the case of crystals it is necessary to define which face is operated upon. The best surface to choose is that of cleavage. The numbers obtained, expressed in kg. per sq. mm., show that Mohs's scale is far from giving a uniform succession of values. Talc figures at 5, but it is untrustworthy, and it should also be preceded by wax and graphite, and followed by gypsum, 14. Rock-salt is 20. Between this and calc-spar (92) there is a great gap, which might well be filled up by sylvine, glauberite, and galena. Fluorspar is 110. Then comes another gap, which should be filled up with scheelite, heaviest silicate flint-glass (170), and light flint-glass (210). Then comes apatite (237), followed closely by adularia (253), which might be succeeded by borosilicate crown glass (274). Quartz, topaz, and corundum figure at 308, 525, and 1150 respectively; and diamond is not as yet determined.—*Wied. Ann.*, lviii, 357; *Proc. Phys. Soc.*, xiv, 296.

12. *Determination of Freezing Points*; by J. A. HARKER. (Abstract from the *Proc. Roy. Soc.*, lx, 154.)—Of recent years great improvements have been made in the construction of accurate thermometers. For their graduation and study, the position of the thread for at least two fixed temperatures must be known with certainty, and one of these is generally the freezing point. According to many observers, the methods at present in use for the determination of this point are unsatisfactory and cannot be relied on, even when considerable precautions are taken, to more than about  $0.001^{\circ}$  to  $0.002^{\circ}$ . The object of the present communication is to describe a method by which more consistent results can be obtained, and which is applicable to all kinds of thermometers.

The method adopted is to cool distilled water in a suitable

vessel, protected from radiation, to a temperature below  $0^{\circ}$ , to insert the thermometer, and then bring about the freezing of the water by dropping in a crystal of ice. The thermometer then rises, and finally attains a steady temperature, differing only very slightly from the true zero.

Within the space allotted to this abstract, it is not possible to describe in detail all the precautions to be adopted and the apparatus employed, and for these reference must be made to the original paper. The following brief outline may, however, be given.

The apparatus consists of two portions, the thermostat and the cooler. The former is a rectangular copper vessel, filled with some liquid, which can be cooled below  $0^{\circ}$  without solidifying.

Generally either refined petroleum or a strong solution of common salt is employed. This vessel communicates by means of two wide tubes with a system of coils in the cooler, through which the liquid can be pumped by a rotary stirrer. These coils are surrounded by a freezing mixture at about  $-8^{\circ}$ , and by this means the circulating liquid can be cooled and maintained for some time at about  $-2^{\circ}$ . The distilled water to be frozen is contained in a tube of about 300<sup>cc</sup> capacity made of clear glass. This is first placed directly into the circulating liquid and cooled quickly to  $-0.5^{\circ}$  or  $-0.7^{\circ}$ . It is then transferred to a copper cylinder lined with polished metal, placed in the center of the thermostat, an annular space of about 1<sup>cm</sup> being left between them. The thermometer whose zero is to be taken is then quickly fixed in position in a spring clamp, the bulb and a considerable length of the stem above the zero being immersed in the water. A crystal of ice is dropped in, and the temperature quickly rises to the freezing point.

For the details of the arrangement for the illumination of the divisions, and taking the readings through the mass of the liquid containing the ice crystals in suspension, reference must be made to the paper.

The amount of ice formed in the liquid varies of course with the undercooling. Experiments made with good mercurial thermometers showed that if ice be present in sufficient quantity, the final temperature attained by the mixture of ice and water is not influenced perceptibly by variation of the temperature of the circulating liquid within fairly wide limits. As, however, it is extremely doubtful whether the indications of any mercurial thermometer can be relied on beyond  $0.001^{\circ}$ , it seemed desirable to control this result by some other means.

A platinum thermometer and bridge were therefore designed, capable of indicating with certainty a change of  $0.0001^{\circ}$ , and a description of the whole arrangement employed to attain this degree of accuracy forms the second half of the paper. The resistances in the bridge were of manganin, whose temperature coefficient is only about  $\frac{1}{20}$  that of the usual resistance alloys, and the plugs usually employed for short circuiting the coils were

replaced by copper bars and mercury contacts of specially low resistance. The thermometers employed were of about 10 ohms resistance, and were provided with the compensating leads, devised by Mr. Callendar. The maximum current which can be used in accurate measurements with these thermometers is about 0.02 ampère, and therefore the galvanometer employed required to be extremely sensitive. The instrument selected was a low resistance astatic one with vertical needle system of the type described by Weiss, and gives at the greatest sensibility at which the zero is steady one scale division for  $1 \times 10^{-10}$  ampère at 2500 scale divisions distance.

With this arrangement the influence of various conditions on the final temperature attained by the mixture of ice and water was studied. The results were found to be in close agreement with the theoretical deductions of Nernst, and it was found that with the right conditions, it was quite easy to keep the temperature in the freezing vessel constant, to within one or two ten-thousandths of a degree for an hour at a time.

The conclusion drawn from the previous experiments made with mercurial thermometers as to the small influence of changes in the external temperature, and in the temperature of the circulating liquid on that of the freezing vessel, was also confirmed, and it was found that in the final form of apparatus adopted, a change of two or three degrees in the temperature of the circulating liquid only caused the temperature of the mixture in the tube to alter by three or four ten-thousandths.

13. *Röntgen Rays and Phenomena of the Anode and Cathode; principles, applications and theories*, by EDWARD P. THOMPSON. Concluding chapter by Prof. WILLIAM A. ANTHONY. 190 pp. 8vo. New York (D. Van Nostrand Company).—This volume contains a series of brief abstracts of the results and methods of many experimenters on the phenomena of the electric discharge, beginning with Faraday (1831) but including particularly the work of the past year upon the so-called X-rays of Röntgen. These notes are in numbered paragraphs arranged somewhat according to special subject under a series of chapters, with frequent cross references designed to call attention to the relation between them. Numerous illustrations are introduced including some forty-five half-tone reproductions of "sciagraphs" obtained by different experimenters. The general public will find this an interesting and convenient digest of the literature of the Röntgen rays.

14. *The Journal of Physical Chemistry*. Edited by WILDER D. BANCROFT and JOSEPH E. TREVOR. Vol. I, No. 1. 68 pp. Published at Cornell University, Ithaca, N. Y. October, 1896. —This new Journal comes forward to take a place not hitherto occupied among the scientific periodicals of the country. It will doubtless receive cordial support from all those interested in the department it represents. The first number contains articles by A. E. Taylor on irreversible cells (pp. 1-20); by F. Wald on



Chemistry and its laws (pp. 21-33); by W. D. Bancroft on Ternary Mixtures, II (pp. 34-50). The latter half of the number is occupied by book notices (pp. 51-58) and reviews of papers (pp. 59-68). The Journal is to be issued monthly, except July, August and September; price \$2.50 per year.

## II. GEOLOGY AND NATURAL HISTORY.

1. *The geology of Somali-land.*—The study at the British Museum of fossils and rocks brought to England by members of the James Expedition, has given Dr. Gregory the evidence for interpreting the general features of the geology of Somali-land. In an article in the Geological Magazine (vol. iii, p. 293)\* for July the following results are announced:

“The Somali-land sequence . . . consists of the following :

1. Marine and subaërial recent deposits.
2. Neocomian limestones and cherts.
3. Duba limestone of uncertain age.
4. Bathonian limestones of Bihin.
5. Red and purple sandstones—unfossiliferous.
6. Archean series. (Gneisses penetrated by pegmatite dykes, etc.)

The discovery of the Bathonian fossils is of great interest. Bathonian rocks are known in Abyssinia from the work of Blanford, Ferret and Galinier, Aubry and Douvillé. They are also well known from the west coast of India in Cutch. They occur in northern Somali-land, exactly on the line joining these two localities. Mrs. Lort-Phillips' fossils are especially of value, as Rochebrune, on the basis of Révoil's collections from Somali-land, has disputed the accuracy of the determination of the Jurassic age of the Abyssinian limestones. The presence of Bathonian fossils in Somali-land, however, shows that, apart from the Abyssinian limestones, there are fossiliferous marine deposits of both Lower Jurassic and Neocomian age in this region of East Africa.

The occurrence of one species (*Parallelodon Egertonianus* Stoliczka) in Somali-land and in India helps to strengthen the idea of the former connection of the Bathonian rocks of India and Somali-land, which is suggested by the apparent extension of these rocks along an east and west line, from Cutch to Shoa. This is of interest, as it throws light on the origin of the interesting fauna and flora of the Golis Range. The report on the collection of plants made in the Golis Range, published in the Kew Bulletin of Miscellaneous Information (No. 105, September, 1895, pp. 211-30), shows that the flora of this district contains a very high proportion of endemic species (69 species out of 350 were new). This appears to be due to two reasons. In the first case, the Golis hills appear to contain limestones, which support a more varied flora than the soil formed by the weathering of the gneiss

\* A note on the Geology of Somali-land, based on collections made by Mrs. E. Lort-Phillips, Miss Edith Cole, and Mr. G. P. V. Aylmer. By J. W. Gregory.

and schist. As travelers generally cross from the lowlands to the plateau by the Sheikh Pass, which has been cut down to the Archean series, they had previously missed this interesting flora.

In the second place, the high proportion of endemic species and the fauna and flora of these hills may be explained by their being inhabited by a group of species which entered the country from land which formerly extended to the east. In the discussion at the Geographical Society on Dr. Donaldson Smith's paper on his journey to Lake Rudolf, Dr. Bowdler Sharpe remarked that some of the Somali-land birds were allied to those of the Cape, and were unlike the representative species that live in the intervening parts of East Africa. It is most probable that the Jurassic rocks of Somali-land are part of a band which once extended eastward into the Indian Ocean, and may have been part of the hypothetical continent of Gondwana-land or Lemuria. This continent was probably separated from Equatorial East Africa, but was connected with the Cape. Thus it is quite possible that some species may have reached both the Cape and Somali-land without entering Equatorial Africa. Hence one of the constituents of the fauna and flora of Somali-land may be a remnant from those of the lost continent of Gondwana-land and Lemuria."

2. *Text-Book of Paleontology*, by KARL A. VON ZITTEL, translated and edited by CHARLES R. EASTMAN, Vol. I, Part I, pp. 1-352, 1896.—American students of geology and paleontology will take especial pleasure in the appearance of this admirable German treatise in English dress. It was originally intended to produce a literal translation into English of the "Grundzüge," immediately following its German edition, and Dr. Eastman, who was then a student at Munich, was selected by the author to conduct the translation. But as the work proceeded, and corrections and additions became numerous, specialists in England and America were consulted, and finally some of the sections were referred bodily to others for thorough adaptation to the needs of those who were expected to use them in the English language.

The Protozoa and Cœlenterata are translated with very slight modifications. A note on p. 82, however, calls attention to the important forthcoming work of Miss Ogilvie on the "*Structure and Classification of Corals*," which will materially modify the classification of the Madrepোরaria, hitherto constructed on the main lines of the Milnes-Edwards and Haines system. The sections on the Crinoids and the Blastoids were revised under the direct supervision of Mr. Wachsmuth, and this part will be found to agree with the masterly monograph of Wachsmuth and Springer now being published by the Museum of Comparative Zoology on "*The Crinoidea Camerata of North America*." The Cystoidea are substantially as in the Grundzüge. Special acknowledgments are expressed for assistance given by Mr. W. Percy Sladen in revising the parts on the Asterozoa and the Echinozoa, and particularly the chapter on Echinoidea, which is

made to accord with the new results published in Duncan's "*Revision of the genera and great groups of the Echinoidea.*"

The chapter on Bryozoa is entirely rewritten by Mr. E. O. Ulrich, whose numerous publications on this group have earned a well merited place in American paleontology. The *Monticulipora* find a place among the tabulate corals (p. 103) and again among the Bryozoa, but this reduplication is due to the fact that the earlier pages were already in type when the chapter on Bryozoa was written, and we are informed by the editor that in revised editions of Nicholson's work as well as of "*Grundzüge*" the Ulrich classification will be adopted.

The credit for having revised and practically rewritten the translation of the entire Brachiopod chapter belongs to Mr. Charles Schuchert. The classification adopted has been taken from his "*Synopsis of American Fossil Brachiopoda,*" now in press, and it is in substantial accord with the recent monograph of Hall and Clarke, and with all the more advanced literature of American writers on the Brachiopoda.

The present part closes with the first few pages of the Mollusca, and it is to be hoped that the remaining parts will be rapidly brought out, since the paleontologist dealing with paleozoic fossils must have the whole of the invertebrates, at least, before him in the discussion of almost any full fauna, and such a work does not attain its best value as a text-book until it is complete.

American students will be particularly grateful to Professor Zittel, not only for supplying them with an English translation, but in allowing such liberal adjustment of the original work to be made by their own specialists. The work has thus become not only an English translation, but an Americanized edition of Zittel's standard work. And we have also to thank the editor for the skill with which he has rendered the German into excellent English while preserving the scientific accuracy of the author.

H. S. W.

3. *Structural details in the Green Mountain region and in eastern New York*; by T. NELSON DALE. (Extract from XVIth Annual Report of the Survey, 1894-95. Part I, p. 543-570. U. S. Geological Survey, Washington, 1896.)—The author has here collected, mainly from the Taconic region, illustrations of inclined, overturned, transverse and unequal folding, false-bedding, obscuration of bedding by cleavage, differential cleavage, cleavage-banding, two and threefold cleavage, cleavage along fault lines, stretching, brecciation, and siliceous segregation, most of which are intended as fresh illustrations of well-known geological principles. One of them, however, "cleavage-banding" is not so familiar, and rather perplexing. At the end is an index to descriptions of related structural phenomena previously published by the author in other U. S. Geological Survey Reports which readers interested in this branch of geology may find useful. The paper has thirty-one diagrams, sketches and photographs.



4. *The Mineral Industry, its Statistics, Technology and Trade in the United States and other countries to the end of 1895.* Vol. IV. Edited by RICHARD P. ROTHWELL. 849 pp. 8vo. 1896. New York and London (The Scientific Publishing Company).—This fourth volume of the *Mineral Industry*, published under the auspices of the Engineering and Mining Journal, brings the subjects discussed down to the close of 1895. The editor-in-chief is Mr. Richard P. Rothwell, but he has had the assistance of a large corps of helpers in the different departments. The many who have used to advantage the earlier volumes of this series will remember that it gives not only a summary of the condition of each industry with respect to amount of material mined at different points, both in this country and abroad, but also a synopsis of the course of the prominent markets, as at New York and London; also in many cases an account is given of the treatment of ores. Special chapters discuss related topics of interest, as the evolution of the anthracite coal trade; labor, wages and accidents in mining; the depth to which it is plausible to think that mining operations may be carried in the future; the application of electricity to mining, etc.

5. *The Botanical Gazette.* Editors, John M. Coulter, *The University of Chicago, Ill.*, Charles R. Barnes, *University of Wisconsin*, J. C. Arthur, *Purdue University*; Associate Editors, George F. Atkinson, *Cornell University*, Volney M. Spalding, *University of Michigan*, Roland Thaxter, *Harvard University*, William Trelease, *Missouri Botanical Garden.* CHICAGO, ILL. PUBLISHED BY THE UNIVERSITY OF CHICAGO.—It gives us great pleasure to note the substantial improvement by which this excellent journal is made to take an assured place in the front ranks of periodical scientific literature. It has been carried steadily forward by the energy and self-denial of its early projectors, under serious discouragements arising from slender pecuniary support and the lack of a permanent home. Happily, its founder and two of its early editors have adhered to it through days of trial, and they now have the justifiable satisfaction of seeing it accepted as an official publication of Chicago University, enlarged in scope, enlisting the services of four associate editors, and commanding the respect of botanists throughout the world. From the outset the editors have evinced good judgment in securing for the *Gazette* illustrations of high order and in insisting on good typographical execution. In the new volume, beginning with July of this year, the same severe taste is manifest, with the result of giving us a technical journal of which every American botanist may feel proud.

G. L. G

6. *The Dualistic Theory of Descent.*—This is the name given by Sachs to a suggestive hypothesis concerning derivation, which he has presented in *FLORA (Marburg)* during recent numbers, the last of which bears date of June 3, in the issue for July 4. The style possesses the charm which has rendered all of the writings of Sachs agreeable reading and leads the reader often to give

his partial adherence to views which on subsequent study he cannot accept. Within the limits of space now at our command we can merely call attention to the attractive papers now referred to, and express the hope that the phylogenetic aphorisms may soon be placed before our readers in a convenient form. G. L. G.

### III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *British Association for the Advancement of Science*.—The annual meeting of the British Association was held at Liverpool during the week beginning September 14th. The gathering was a notable one in various respects; as regards size it ranked among the largest, the attendance aggregating nearly 3200. Much interest was aroused by the inaugural address, delivered by the President, Sir Joseph Lister, upon the germ theory and antiseptic methods in surgery. Other important addresses were delivered before the several sections, as that by Prof. J. J. Thomson upon the Röntgen rays, reprinted in part (from *Nature*) in the present number. This subject also formed the theme of numerous papers in the physical section.

The next meeting is appointed for August, 1897, at Toronto, Canada, under the Presidency of Sir John Evans. This will be held simultaneously with the meeting of the American Association at Detroit, and arrangements have already been made for an exchange of courtesies between the two scientific bodies. The meeting for 1898 is to be held at Bristol, and that for 1899 at Dover, the latter in conjunction with the meeting of the French Association appointed for Boulogne on the opposite side of the British Channel.

2. *Report of the Sixth Meeting of the Australasian Association for the Advancement of Science*, held at Brisbane, Queensland, January, 1895. Editor, JOHN SHIRLEY. 875 pp. Sydney, 1896.—This volume, recently received, contains the record of the meeting of the Australasian Association at Brisbane, Queensland, in January, 1895. It includes the various Presidential addresses and also a considerable part of the long list of papers presented and grouped under the usual sections.

3. *Ostwald's Klassiker der Exacten Wissenschaften*.—The following are the titles of the most recent additions to Ostwald's valuable collection of scientific classics:

Nr. 76. *Theorie der Doppelten Strahlenbrechung, abgeleitet aus den Gleichungen der Mechanik* von F. E. Neumann (1832). 52 pp.

Nr. 77. *Ueber die Bildung und die Eigenschaften der Determinanten. (De formatione et proprietatibus Determinantium.)* Von C. G. J. Jacobi (1841). 73 pp.

Nr. 78. *Ueber die Functionaldeterminanten (De determinantibus functionalibus).* Von C. G. J. Jacobi (1841). 72 pp.

Nr. 79. *Zwei Hydrodynamische Abhandlungen* von H. Helmholtz. I, *Ueber Wirbelbewegungen* (1858). II, *Ueber discontinuirliche Flüssigkeitsbewegungen* (1868). 79 pp.

## OBITUARY.

M. HIPPOLYTE FIZEAU, the French physicist, died recently at the age of seventy-seven. His name will be long remembered in connection with his determination of the velocity of light.

"Born in 1819, Fizeau was only thirty years of age when his paper, 'Sur une expérience relative à la vitesse de propagation de la lumière,' appeared in the *Comptes Rendus*. In this he put forward his plan of rotating a wheel having round its rim alternate teeth and spaces of equal width, so that these teeth and spaces should alternately intercept and allow to pass a beam of light from a source, and so adjusting the speed of rotation that the time occupied by the light in traveling from the wheel to a mirror and back again, should be equal to the time taken by the rim of the wheel to advance through a space equal to an integral number of times the width of a tooth or space. Curiously enough, the other experimental method of finding the velocity of light was described by Foucault in the very next volume of the *Comptes Rendus*. In some respects the latter method—that of the revolving mirror—was even more striking than that of Fizeau. It allowed the velocity of light to be determined within an ordinary room, and, besides, enabled the question as to whether light traveled more or less quickly through a more refractive medium to be decided by direct experiment.

Another experiment of capital importance with which the name of Fizeau will ever be honorably associated is that by which he determined the amount of drift of light-waves in a transparent medium in motion. According to a theory given by Fresnel, the velocity of drift of ether-waves in a medium moving with velocity  $u$  is  $(1 - 1/\mu^2)u$ , where  $\mu$  is the index of refraction of the medium. This conclusion of Fresnel was verified more lately by the experiments of Airy and Hoek, which proved, in opposition to the statement of Klinkerfues, that no change in the constant of aberration is observed when the tube of the observing telescope is filled with water. But it was tested directly by Fizeau in the most simple and beautiful manner. Two tubes were arranged side by side, and water was forced at a considerable speed (as much as seven meters per second) along one tube and back by the other, while a beam of light was split into two parts, which were sent round the tubes, one with the stream, the other against the stream, and then brought together again and tested for interference produced by the virtual difference of path traversed, arising from the motion of the water. The result gave exactly the formula quoted above, and has been confirmed by very careful experiments made comparatively recently by Michelson and Morley."—*Nature*, Oct. 1.

SR. LUIGI PALMIERI died at Naples in the early half of September at the age of eighty-nine. He was director of the Observatory at Vesuvius and made important contributions to meteorology and seismology.



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VOL. II—[WHOLE NUMBER, CLII.]

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WITH PLATE VI.

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THE

# AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. LVII.—*Archelon ischyros*: A new gigantic Cryptodire Testudinate from the Fort Pierre Cretaceous of South Dakota; by GEO. R. WIELAND. With Plate VI.

ALTHOUGH it is now some twenty years since Cope first described the genus *Protostega*, little or nothing has been added to our knowledge of it by the description of new American species. And save the Italian *Protosphargis* of Capellini this branch of the Sphargididæ has remained a quite isolated one.

I, therefore, propose to describe at this time certain portions of a new gigantic testudinate closely allied generically, from the Fort Pierre Cretaceous of South Dakota, for which the name *Archelon ischyros* is proposed.

The skeleton consists of carapace complete with ribs nearly entire, the procoraco scapulars and coracoids, one humerus complete, both femurs, radius and ulna, tibia and fibula one each, a number of carpals and tarsals, a number of phalanges, most of the cervical and caudal vertebræ, all the dorsal vertebræ, the pelvis entire, a nearly or entirely complete set of spine set plastral shields, fragmentary marginals, and certain bones whose reference has not as yet been decided upon.

As all the larger bones were found in place and the material for a restoration is so exceptional,—one will be given in a short time.

## *General description.*

*Carapace*.—The carapace is composed of nine pairs of pleuralia, and eight medial pairs of plates or neuralia, followed by one single medial plate and the pygal, or 36 in all. These plates are all very thin and of finely striate surface. They unite very

imperfectly by means of loosely doubled interlocking and overlapping digitations grading into frequent free spines posteriorly. These digitations are mostly long, thin and ribbon-like, and produce a junction quite different from the usual suture. In many cases there is an appearance such as would result if the digitations of the one plate had lain upon the surface of the adjoining plate when it was in a plastic condition and thus raised rounded ridging about their edges. The order of the digitations and their size is rather irregular.

With the exception of the medial pair of plates corresponding to the eighth dorsal vertebra and the single medial following, which are small and crowded, and the pygal, which is comparatively large and heavy, the plates of the carapace are quite regular in size. The width and thickness are quite the same throughout, with a shade more of development of both in the pelvic region. One of the chief features of the carapace is the arching into a heavy dorsal ridge, beginning just back of the region of the first dorsal vertebra, and from thence continuous, except in the sacral region. It marks the position of the neural spines, and is very distinctly grooved from anteriorly to the region of the eighth dorsal vertebra. Immediately over the neural spines this groove inclines to widen, deepen and send out asteriations. In life, these grooves were no doubt filled with horny material, and the animal may have borne a dorsal row of spines. It is the appearance along this groove that makes me regard the medial carapace as consisting of a double row of plates. If these are not to be regarded as separate ossifications, the whole number of plates would be 28, consisting in the nine pairs which are morphologically\* simply uncinoid expansions of the ribs, and a medial row of plates, ten in number. I shall have more to say about the carapace at a subsequent time. It consists of very thin, but dense and splintery, bone imbedded in exceedingly hard, indurated marl. In one section, through the medial dorsal ridge just back of the third rib, there is a large open space above the centrum, the thickness of the carapace being in no place much over  $\cdot 5\text{cm}$ . At another break, exposing in section more nearly through the end of a centrum, back of the sixth rib, the outer carapace may be said to form a very open V, consisting of very thin layerings, while there is a very thin laminated to honeycombed connection with the summit of the underlying neural spine  $\cdot 3\text{cm}$  in thickness by  $1\text{cm}$  in vertical height. There is a tendency to very small thin and irregular bony projection from both bases of this connection. In the

\* On relation between carapace and endoskeleton, see Baur, Science, March 23, 1888; also a much more extended treatment in the Biologische Centralblatt, Nr. 5, 6, 1889 (Erlangen).



pelvic region the connection between the carapace and neural spines is no more than one of contact, while in the sacral and caudal regions there is no connection whatever.

*Measurements of Carapace.*

|  | Meters.   |
|--|-----------|
| Total length of portion preserved (exclusive of nuchal and part of pygal)..... | 1.515     |
| Estimated total length, exclusive of nuchal..                                  | 1.70      |
| Breadth between 2nd and 3rd ribs.....  | .40       |
| “ “ 5th and 6th “ .....  | .40       |
| “ “ 6th and 7th “ .....  | .45       |
| “ “ 7th and 8th “ .....  | .36       |
| “ “ 8th and 9th “ .....  | .28       |
| Narrowest portion of pygal anteriorly.....                                     | .10       |
| Thickness of carapace.....   | .002-.015 |

*Ribs.*—The ribs, of which there are nine pairs, are remarkable for their distal increase in thickness, only 2.5<sup>cm</sup> in thickness at the edge of the carapace; the distal two-thirds of their length is very massive. In the five anterior pairs the thickness three-fourths out, that is at 75<sup>cm</sup> from the centra, is from 4 to 5<sup>cm</sup>. The width is quite regular, and the surfaces, for the four-fifths of the length free from the carapace, is markedly striate longitudinally. In cross section the ribs are T-shaped as they emerge from the carapace, medially they are triangular merging into flattened elliptical distally. The two anterior and two posterior pairs have shallow longitudinal grooving on their upper surface.

In cross-section the ribs show, following a very thin, dense outer layer of bone, a concentric lining, grading into a somewhat spongy interior.

*Measurement of Ribs.*

|   | Meters. |
|---|---------|
| Length of 1st rib.....  | .95     |
| “ “ 2nd “ .....   | 1.01    |
| “ “ 3rd “ .....   | 1.02    |
| “ “ 4th “ .....   | 1.02    |
| “ “ 5th “ .....   | 1.01    |
| Average thickness of above ribs as they emerge from carapace.....   | .025    |
| Thickness of third and fourth ribs half way out, .....  | .05     |
| Width half way out, 1, 2, 3, 4, 5, 6, 7, 8, 9, respectively, .075, .075, .078, .075, .07, .065, .06, .055, .05. |         |

*Vertebral Column.*—Five of the cervical centra with three arches were recovered, the last three being in place. The neu-

ral arches articulated with the centra, and were X-shaped bodies with spreading feet which stood well forward on the centra. Subquadrilateral projections extending well forward bear the prezygapophyses, which are somewhat broken away, but seem to have looked forward rather than upward. Immediately over the neural canal the neural spine retreats rather sharply, at the same time taking a keel shape anteriorly, but posteriorly dividing and spreading out into alæ, which form a distinct deep pit and bear on their under surfaces the postzygapophyses. Posteriorly, there is a groove connecting this cup with the neural arch. Anteriorly, the neural spine does not fork as distinctly above as in the very similar vertebræ of *Protostega gigas* Cope.\*

The centra are very heavy and strong bodies, and indicate a neck of enormous strength. They are procœlous, and flat in front, except for the articulating concavity. The anterior upper half rises collar-like on either side of the neural canal, forming an upward and forward-looking articular surface, on which rests the base of the neural arch. The neural canal is scooped out very deeply, and as there is a somewhat similar longitudinal cavity on the nether side, the vertical distance through the centrum is considerably lessened. There are also two similar cavities beneath on the sides, with a heavy ridge, with convex edge, between these and the ventral cavity. Leading from the two lateral concavities around to the neural concavity is a very distinct groove, getting shallower just as it reaches the upper face.

*Measurements of 3rd or 4th Cervical Vertebra.*

| The centrum.  | Meters.                           |
|---|-----------------------------------|
| Length .....  | ·095                              |
| Width .....   | ·140                              |
| Diameter of anterior concavity                            | } vertical ·065<br>horizontal ·08 |
| Diameter of posterior convexity                           |                                   |
| Depth between cup of neural canal and nether groove ..... | ·06                               |
| The articulating neural arch.                             |                                   |
| Total length .....  | ·122                              |
| Basal width (total) .....                                 | ·11                               |
| Width between the bases .....                             | ·045                              |
| Width at top .....  | ·075                              |
| Distance from base to summit of neural canal ..           | ·065                              |
| Total vertical depth of neural canal .....                | ·08                               |

\* Cretaceous Vertebrata of the West, Plate XI, fig. 5 a, b, c, d.

The *dorsal vertebræ*, ten in number, have not as yet been completely examined. They present, inferiorly, a striking resemblance to those of *Protosphargis* as restored by Capellini, but with this important exception: in *Protosphargis* the third dorsal vertebra is the largest, in *Archelon* the sixth is by far the largest.\* They have nearly, or wholly, flat ends. The neural arches are evidently rather flat bodies, articulating with the centra and forming the heavy dorsal ridge mentioned before. They have little or no connection with the carapace. The dorsal centra increase in size to the sixth. The seventh, eighth and ninth rapidly diminish to the sacral, which are short and flat, and three in number. Following the sacral were five or more *caudal vertebræ* with articulating neural arches, and then fully ten whose arches, like those of the cervical vertebræ of *Protosphargis* and unlike the caudal vertebræ of *Sphargis*, were homologous parts of the centra.† Presumably these were situated beyond the pygal. Of these caudal vertebræ, ten or more were recovered, wholly or in part.

*Coracoid*.—The coracoid is a shapely and comparatively slender bone, 77<sup>cm</sup> in length. The lateral surface is finely striate, with larger parallel striations distally. The articulating surface is very distinctly tuberculated, some of the tuberculations being somewhat rounded, others quite conical and so much as 1<sup>cm</sup> across at base and 1.5<sup>cm</sup> high.

The articular face is strongly convex anteroposteriorly, and a little less so laterally, but in such manner that near the outer edge of the surface for the procoracoscapula there is a slight concavity, while the humeral surface is broadly flat and looked well downward and forward. For the first two-fifths of its length the shaft is in section isosceles right triangular, with the right angle on the inner side. The upper inner side of the shaft, however, takes a long turn to the outer face just beyond the middle, leaving the distal end comparatively thin and flat. The coracoid is much larger than in *Protostega*, as are all the bones, but bears strong resemblances.

#### *Measurements of Coracoid.*

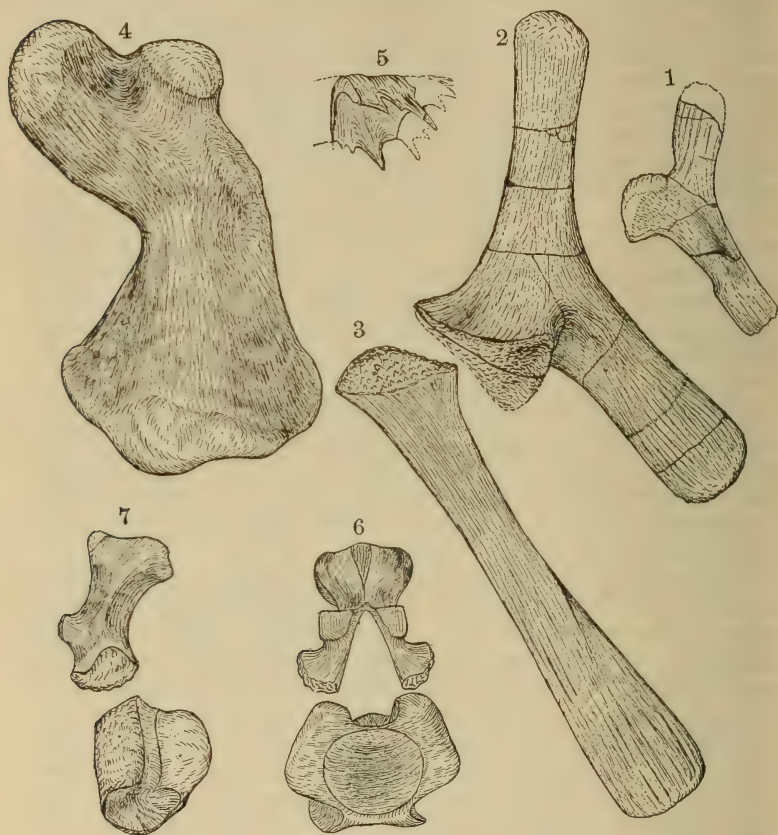
|  | Meters. |
|--|---------|
| Greatest length .....                    | ·77     |
| Greatest distal width .....              | ·142    |
| Least circumference of shaft .....       | ·25     |
| Greatest length of articular face .....  | ·20     |
| Greatest breadth of articular face ..... | ·145    |

\* Il Chelonio Veronese, Reale Accad. dei Linci, 1883-4 (Rome).

† See the beautiful memoir,—Osteologie du Sphargis Luth. (*Sphargis coriacea*) par M. Paul Gervais, pp. 199-227 Planche V.—VIII. Nouvelles Archives du Museum, Tome 8, 1872 (Paris).



*Procoracoscapular*.—The procoracoscapular strongly resembles that of *Protostega*, the chief differences being that while the scapula of *ischyros* is rotund on the outer side, that of



*PROTOSTEGA GIGAS* Cope.—1. Right Scapuloprocoracoid, one-tenth natural size. And from same individual as Plate VI.

*ARCHELON ISCHYROS*.—2-7. All from the same individual as Plate VI, and one-tenth natural size, except 6 and 7, which are one-sixth.

2. Left Procoracoscapular, approximate outer view.
3. Left Coracoid Procoracoscapular, approximate outer view.
4. Left Humerus, inside view.
5. Portion of a Marginal.
6. Third or fourth Cervical Vertebra, front view.
7. The same, side view.

*Protostega* has a well-marked longitudinal depression near the middle and a shoulder-like expansion of the outer edge of the distal end. On the contrary, however, while the shaft of the procoracoid of *Protostega* is quite regular in outline, that of

*ischyros* bears an elongate ridge just opposite the coracoid border. The scapula and procoracoid stand at the same angle of  $125^{\circ}$  in both cases. Distally, both these elements are subtriangular in section, with the vertices well on the inner side, leaving the inner faces somewhat ridged distally, though medially there is very distinct flattening.

The outline of the articular face is approximately that of an isosceles trapezoid, with a broadly saddle-shaped convexity angling across it so as to leave on the one side of the upper and wider end of the articular face a concavity for the reception of the coracoid, and on the other side a broad, rather flat, humeral expanse. The entire articulating surface, like that of the coracoid, is tuberculated. The lateral surfaces are finely striate, the procoracoid having additional large striations, like those of the coracoid.

*Measurements of Procoracoscapula.*

|   | Meters. |
|---|---------|
| Width of neck.....  | ·171    |
| Width of articular extremity .....                                | ·21     |
| The greatest transverse width of same .....                       | ·13     |
| Length of precoracoid to inferior border of the scapula .....     | ·35     |
| Length of scapula to inferior border of the precoracoid .....     | ·485    |
| Length of the scapula to the glenoid cavity...                    | ·45     |
| Distance between extremities of the scapula and precoracoid ..... | ·66     |
| Width of precoracoid proximally .....                             | ·117    |
| Least width of precoracoid .....                                  | ·107    |
| Distal width of precoracoid .....                                 | ·127    |
| Distal thickness of precoracoid .....                             | ·10     |
| Least width of scapula .....                                      | ·078    |
| Proximal thickness of scapula .....                               | ·046    |
| Distal width of scapula .....                                     | ·095    |
| Distal thickness of scapula .....                                 | ·085    |

*Humerus*.—The humerus agrees with that of *gigas* in that it is flat, with a heavy globular head and an immense trochanter, which, with its base, is even larger than the head. In fact, though the head possesses a large articular surface, its general aspect is that of being a secondary projection from the trochanter. From the massive proximal end the shaft constricts slightly near the middle, at the same time flattening, but again expanding and thickening in the lower half into a flat, but massive, fan-shaped distal extremity, making an angle of about  $105^{\circ}$  with the proximal end. The most notable variation from *gigas* (also *tuberosa*),\* aside from dis-

\* Cretaceous Vertebrata of the West, p. 113.

parity in size, is in the minor development of the small trochanter, which is little more than a rugosity for ligamental attachment. It is 17<sup>cm</sup> long and 11 wide, and subovoid in shape with the greatest expansion above, and slight concavity on its inner and obliquely upward facing expanse. The general aspect is, however, moderately convex, owing to a heavy, oblong ridge which crosses obliquely from the upper, outer portion to the lower, inner edge. In *gigas* the small trochanter is prominent, being set on an ala 8<sup>cm</sup> in length and nearly 2·5<sup>cm</sup> in height. The bases, therefore, bear out the general proportions of the two bones.

The bicipital groove is a wide and heavy channel, much more marked on the inner side, where it expands into a subovoid concavity whose greatest depth is about 2<sup>cm</sup>. The inner surface of the fan-like distal end is longitudinally concave, both anteriorly and posteriorly, while the central portion forms a massive, expanding convexity, terminating in the articular face.

The outer surface is very flatly convex, and conspicuous for a deep groove 5<sup>cm</sup> wide and 4<sup>cm</sup> deep, as it ends in the articular surface. The posterior border of this groove lies in the exact distal center. The distal articular surface shows no very distinct divisions. It is both laterally and anteroposteriorly convex, and mostly posterior to the great distal groove, and the centrally placed enlargement of the inner aspect which receives it. The surface of the humerus is covered with minute striæ, with larger striations, about 1<sup>mm</sup> wide and several centimeters long, at short intervals. (Of the humeri, the left is entire, but only the distal third of the right was procured.)

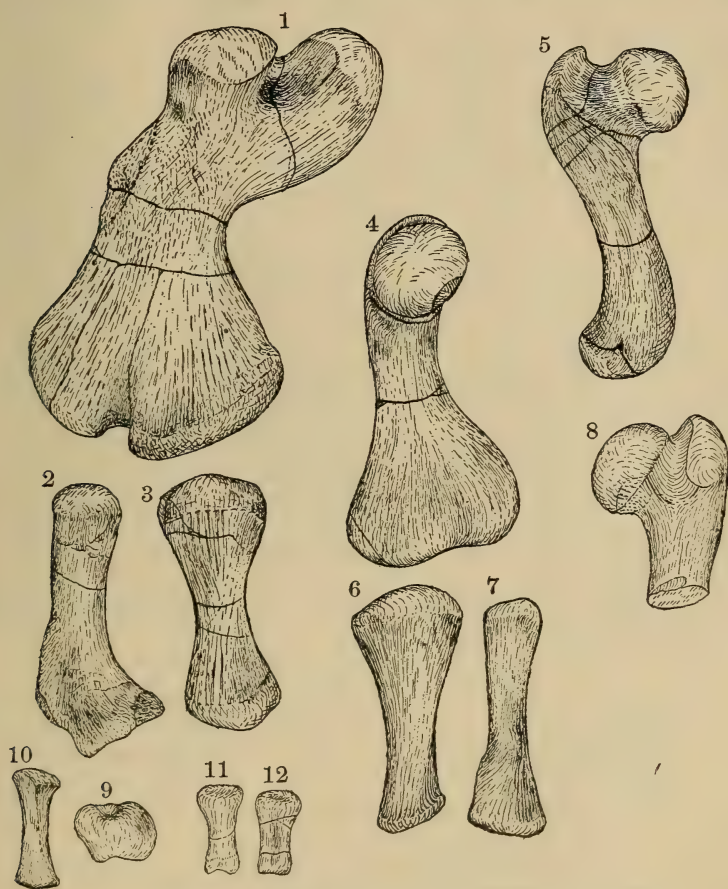
#### *Measurements of Humerus.*

|   | Meters. |
|---|---------|
| Greatest length .....                               | ·65     |
| Length from head .....                              | ·58     |
| Width at head, antero-posterior .....               | ·28     |
| Greatest circumference about base of the head ..... | ·50     |
| Circumference of great trochanter .....             | ·45     |
| Least width of shaft .....                          | ·17     |
| Least thickness of shaft .....                      | ·09     |
| Circumference at least width of the shaft .....     | ·435    |
| Greatest distal width .....                         | ·34     |

*Ulna*.—The ulna is short and comparatively massive, but lacks the immense proportions of the humerus. The proximal articular surface is large and quite regular in outline, flat from side to side, and moderately convex antero-posteriorly (see dimensions). Anteriorly the proximal end bears a broad and shallow groove, disappearing at the middle of the shaft and



reappearing distally as a distinct concave expansion looking forwards and downwards as it rather abruptly merges into the articular surface. The bone has a distinct twist, the trend of the distal articular surface standing at an angle of  $75^{\circ}$  to that



ARCHELON ISCHYROS.

All one-tenth natural size and from the same individual as Plate VI.

1. Left Humerus, outer view.
2. Left Radius, outer view.
3. Left Ulna, outer view.
4. Left Femur, outer view.
5. Left Femur, anterior lateral view.
6. Right Tibia, outside view, drawn as the left tibia.
7. Right Fibula, outside view, drawn as the left fibula.
8. Proximal of Femur, posterior view.
9. Carpal (?)
- 10, 11, 12. Phalanges.

of the proximal. The articular surfaces are in area and outline nearly similar, except that owing to the concavity just mentioned the distal face is very slightly crescentic. In its general aspect it is concave and divided by a saddle-shaped antero-posterior ridge into two subequal areas, the exterior and smaller being somewhat elliptical, the interior and larger double concave in outline.

The surface striations are not so distinct as those of the humerus, tending to flatten and interlace. There is very slight pitting and grooving with a tendency to fluting at the extremities, especially the distal. When closely examined with a reading glass the surface is found to be quite ornate.

The ulna is a very compact bone of great strength and the unequal size as compared with the humerus is apparent rather than real. Taken as a homologous part of the huge forelimb that formed the propeller of the largest known marine testudinate, it was admirably adapted to its purpose.

*Radius*.—The radius, like the ulna, is short and its peculiar distal bow served to give width to the forearm without reducing its strength. The outline of the distal articular surface is that of an isosceles right triangle with the vertex external. It is but slightly concave centrally.

The surface is like that of the radius except along the anterior edge, which is slightly rugose along its entire length.

The set of the distal faces of the radius and ulna was slightly toward each other and they formed a strong base for the massive carpals. Of these one is figured. The phalanges recovered are not of unusual length. Several are figured.

#### *Measurements of the Ulna.*

|                                | Meters.       |
|--------------------------------|---------------|
| Length .....                   | ·33           |
| Proximal diameters .....       | ·088 and ·138 |
| Least diameters of shaft ..... | ·054 and ·063 |
| Distal diameters .....         | ·093 and ·14  |

#### *Measurements of the Radius.*

|                                |                |
|--------------------------------|----------------|
| Length (greatest) .....        | ·35            |
| Proximal diameters .....       | ·049 and ·088. |
| Distal diameters .....         | ·082 and ·114  |
| Least diameters of shaft ..... | ·05 and ·067   |

*Femur*.—The femur is proportioned to the humerus as in *Thalassochelys caretta*. The head stands out at a full right angle on a heavy neck, high and prominent, the articular surface being very convex ovally, the largest diameter bearing an angle of about 45° to the main axis of the humerus. The great trochanter rises well above the head as a somewhat semi-

ovoid projection whose inner boundary as seen from above is a very shallow sigmoid curve. The trochanteric fossa is narrow and deep posteriorly, but widens and becomes slightly shallower immediately in front of the head, again narrowing and disappearing just beneath the head. Just above the most constricted portion of the shaft on the outer side is a lesser trochanter. It is merely a slight inconspicuous convexity. The distal extremity is broad and heavy with a marked downward turn. It is very regular in outline, the external and internal condyles being nearly equal and the intercondylar fossa very shallow. The surface of the bone, like that of the humerus is striate, the striations being most marked distally, with slight longitudinal pitting.

*Measurements of left Femur.*

|  | Meters.       |
|--|---------------|
| Extreme length .....                               | ·46           |
| Diameters of head .....                            | 11·5 and ·129 |
| Diameter of neck .....                             | 0·8 and ·11   |
| Transverse distance through great trochanter ..... | ·185          |
| Least diameters of shaft .....                     | ·075 and ·095 |
| Greatest distal breadth .....                      | ·23           |
| Greatest distal thickness .....                    | ·105          |

*Tibia*.—The tibia is nearly as large a bone as the ulna, fully as large proximally. There are two slight concavities in the proximal articular face for the reception of the femoral condyles. These are separated by a triangular convexity heaviest on the outer side. The outline of the articular face is that of an ellipse very distinctly flattened on the inner side. The distal articular face is flatly convex and broadly elliptical in outline. It is expanded into a kind of collar or foot for the shaft.

*Measurements of left Tibia.*

|  | Meters.       |
|--|---------------|
| Length .....   | ·33           |
| Antero-posterior length of proximal articulating surface ..... | ·15           |
| Transverse measure .....                                       | ·10           |
| Least diameters of shaft .....                                 | ·042 and ·061 |
| Diameter of distal extremity .....                             | ·105 and ·109 |

*Measurements of left Fibula.*

|                                   |               |
|-----------------------------------|---------------|
| Length .....                      | ·31           |
| Greatest proximal diameters ..... | ·082 and ·085 |
| Least diameters of shaft .....    | ·035 and ·045 |
| Distal diameters .....            | ·108 and ·085 |



*Fibula*.—The fibula is a much smaller bone than the tibia proximally, but nearly of the same size distally. The proximal extremity is subquadrilateral in outline with the long side turned to the tibia. Just beneath the articular face in the outer side there is a broad longitudinal scallop. Distally the bone expands, and the articular face is somewhat convex, and elliptical in outline, with a notch for the articulation with the tibia. These two bones have some resemblance to the tibia and fibula of *Protosphargis*.

#### Dimensions.

The very great width of *Archelon* as compared with either *Protostega* or *Protosphargis* will have been noticed. The ribs in the middle dorsal region are quite exactly 1<sup>m</sup> in length; adding 13<sup>cm</sup> as the approximate width of the centra, and 12<sup>cm</sup> as the additional width due to the marginals, assuming them to have been present, we obtain a total width of 2·25<sup>m</sup>; that is of more than 2<sup>m</sup> after making full allowance for dorsal curvature, which must have been slight. If proportioned then as in *Thalassochelys caretta* the total length would be 11 feet. From the vertebral column the same length is indicated. From the five cervical vertebræ the average length would seem to be 9<sup>cm</sup>. These vertebræ must have supported an enormous head, so that ·60<sup>cm</sup> is certainly the lowest cranial length that can be assigned. The caudal vertebræ are estimated at ·70<sup>cm</sup>; that is:

|                                    | M.   |
|------------------------------------|------|
| Cranial length .....               | ·60  |
| Eight cervical vertebræ .....      | ·72  |
| Ten dorsal " .....                 | 1·35 |
| Three sacral " .....               | ·15  |
| Eighteen (?) caudal vertebræ ..... | ·70  |

---

3·52 or 11 ft. 4 in.

This latter will no doubt be a very little less than the actual length.

The most striking feature of this huge animal was formed by the massive forearms, which had a spread of from 16 to 20 feet. Had they had the proportions of *Thalassochelys* the distance would be 20 feet. But there is a wide difference in the structure of the two arms, and I favor the lower estimate.

The length of body I assign to *ischyros* is considerably less than that first estimated for *Protostega* by Prof. Cope and later by Hay on the basis of the hypo- and hyoplastron,\* notwithstanding the great disparity in skeletal weight. While it is scarcely permissible to make calculations based so entirely

\* Field Columbian Museum Publication 7, Chicago.

upon relations obtaining in different genera, I do think that when a complete skeleton of *Protostega* is once obtained it will be found to lack considerable of the enormous length which has been assigned to it. The cervical vertebra figured by Cope is of much the same size as in *Protosphargis*. Also, as Cope found ten ribs, he must have had at least one approaching the longest in length. From comparison of this kind including *Sphargis* itself, *Protostega gigas* must have been less than three meters in length.

### *Systematic.*

In attempting to place the relationship of *Archelon* in existing classifications we are faced by some very heterogeneous characters.

From the characters which have been given I think it will be accepted that the fossil under consideration stands more nearly on the border line between the two *cryptodire* divisions than any form yet described. The endoskeleton strongly resembles that of *Protostega* and *Protosphargis*, while a connection, though slight, between carapace and endoskeleton points to the *Chelonidæ*. I cannot pass the strong likeness of the shoulder girdle, nor the great similarity in the vertebræ. I would define *Protosphargis*, *Protostega*, and *Archelon* as the gigantic Upper Cretaceous representatives of three genera of the *Dermochelydidæ* with the approach to the *Chelonidæ* in the order named.

### *Occurrence.*

*Archelon ischyros* was obtained near the South Fork of the Cheyenne River, about 35 miles southeast of the Black Hills in the uppermost Fort Pierre or No. 4 of the Upper Cretaceous. The skeleton lay deeply imbedded at the side of a small ravine, extending out from the base of a butte of typical Miocene. It had formed the nucleus of a lenslike mass of very hard marl. The excavation of the ravine had no doubt broken down the portion containing the head and right forearm but a year or two since. At the time of interment the skeleton may have been subjected to the action of strong currents, coming from the direction in which it headed, as would be indicated by the fragmentary marginals near the head, the absence of smaller bones, phalanges and caudal vertebræ, except somewhat to the rear and beneath, and furthermore to the fact that the third and fourth (?) cervical vertebræ, with their articulating neural arches, were lodged between the carapace and plastron just against the coracoid full two feet out of their

natural position. All this could be due of course to scavengers, but I am strengthened in the opinion that it was owing to currents from the fact that across the Miocene Butte not more than a half mile away, on very much the same horizon, there were several very distinct gravel strata, the gravel ranging in size from one to three inches in diameter.

The vertical section above the position of the fossil was approximately as follows :

|                   |  |
|-------------------|--|
| <i>Miocene</i>    | { “ Buttes ” with a thickness of from 75 to 100 feet. Flat topped ( “ railroad buttes,” as locally termed because of their embankment-like appearance) owing to a hard flinty to opalaceous layer which caps them. Mostly hard grayish white clays and marls, weathering into red boulders containing frequent remains of <i>Testudo</i> , especially about 30 feet from the summit.   |
| <i>Cretaceous</i> | { Gravelly clays with large flow-and-plunge structure only to be noted in the most favorable positions among the expanse of weathering hills ; in most places appearing as a plain gravelly layer one or two feet thick, although the actual thickness is fifteen feet.<br>Light red or yellow marly clays containing <i>Inoceramus</i> , and very rarely <i>Baculites</i> , with frequent masses of septaria, 30 ft.<br>Deep red to black “ gumbo,” 5 ft.<br>Thin band of yellow marly clay, 5 in.<br>Deep red to black marl or “ gumbo,” 5 ft. |

Underneath the plastron were found four or five species of Mollusca poorly preserved. There were also found in good preservation scales of a fish allied to *Beryx*, also of an unreferred *Malacopterygian*, and a shark's tooth—a very broad-toothed *Lamna*.\*

\* As a matter of convenience these two references are added : A. S. Woodward, On Leathery Turtles Recent and Fossil, Proceedings Geologist's Association, vol. x. Also, Die Chelonier der Norddeutschen Tertiarformation (contains a description of *Pseudosphargis ingens* von Könen) von W. Dames, Palaeontologische Abhandlung, Jena, 1894.



ART. LVIII.—*Examination of Specimens from Chichan-Kanab, Yucatan*; by JAS. LEWIS HOWE and H. D. CAMPBELL.

IN 1894 Mr. E. H. Thompson of Merida, Yucatan, in connection with his archæological researches, collected and forwarded to Prof. F. W. Putnam specimens of water and earth deposits from "the Chichan-Kanab (little sea), an almost unknown lake over six leagues long situated far into the territory of the Sublemdo Indians" in the peninsula of Yucatan. These specimens were placed by Prof. Putnam in the hands of one of us for examination; they were as follows:

"No. 8. Specimen of incrustation found twenty yards from present lake edge March 6, 1894."

"No. 9. Encountered one foot beneath alluvium deposit half league from foot of Lake Chichan-Kanab."

"Spec. 172. Water taken from one yard off shore upper end Chichan-Kanab."

"Spec. 1189. Water taken off middle of Lake Chichan-Kanab, State of Yucatan, Mexico."

No. 8 was a light buff crystalline mass which on analysis proved to be gypsum.

No. 9 was a light gray mass resembling dried mud. It was easily friable and could be rubbed in the fingers to a fine powder. This like No. 8 was almost pure gypsum, a small amount of vegetable matter being present. A portion was dissolved in water and two equal portions of the solution analysed, one for calcium and the other for sulphuric acid. 0.0260 grams calcium and 0.0612 grams  $\text{SO}_4$  were found. The formula  $\text{CaSO}_4$  would require 0.0255 grams calcium for 0.0612 grams  $\text{SO}_4$ . Two grams of the material lost on 22 hours heating at  $160^\circ$  0.4083 grams or 20.42 per cent. At red heat the total loss was 0.4323 grams or 21.62 per cent. The percentage of water in gypsum is 20.93 per cent. Under the microscope the powder was seen to consist of small crystals.

Regarding this gypsum, Prof. H. D. Campbell reports as follows: The powder consists of lenticular crystals, not rounded grains nor crystal aggregates, nor as far as observed is twinning shown. The largest crystals have a diameter of  $0.15^{\text{mm}}$  and a thickness of  $0.06^{\text{mm}}$ . The smallest ones still appear as powder under the higher powers of the microscope. The crystals show a more or less hexagonal outline, indicating the presence of prismatic and clinopinacoidal faces. Curved faces run up toward a point and appear to represent the faces of pyramid and dome. When dissolved in water and recrystallized, they assume the more usual forms of gypsum crystals.

Specimen 172. The amount of water in each of the two specimens was less than 350<sup>cc</sup>, precluding the possibility of a full and accurate analysis. This specimen was perfectly clear and without sediment except a little sand. Without odor and with no perceptible taste. Reaction neutral. On evaporation crystals of gypsum began to crystallize out with slight concentration.

Analysis showed the following per liter :

|                       |             |
|-----------------------|-------------|
| Ca .....              | 0.865 grams |
| Mg .....              | 0.313       |
| K .....               | 0.025       |
| Na .....              | 0.301       |
| SO <sub>4</sub> ..... | 3.361       |
| Cl .....              | 0.368       |

From this it appears that the principal salt in the water is calcium sulphate with smaller quantities of sodium sulphate and magnesium chloride.

No other bases or acids were found, and bromine, iodine, strontium, barium, magnesium and iron were shown to be absent by as careful examination as the quantity of water permitted. Organic matter was also absent.

Specimen 1189, water from the middle of the lake, was perfectly clear when opened, with a slight black rather flocculent deposit. It had a strong odor of hydrogen sulphide and a somewhat bitter taste. Reaction neutral. As soon as the odor of hydrogen sulphide was detected it was resealed, but before it could be examined (a few hours) it had given a copious deposit of sulphur.

Hydrogen was then led through the water for eighteen hours, the H<sub>2</sub>S not precipitated being absorbed in caustic soda, and estimated as As<sub>2</sub>S<sub>3</sub>. The precipitated sulphur was recovered as far as possible by extraction with rectified carbon disulphide in which it was soluble. The amounts from 345<sup>ccm</sup> of water are as follows, calculated per liter :

|                                     |  |
|-------------------------------------|--|
| Hydrogen sulphide dissolved .....   | 0.01008 <sup>grm</sup> = 6.64 <sup>ccm</sup> |
| “ “ from precipitated sulphur ..... | 0.3942      25.91                            |

Total hydrogen sulphide per liter ..... 0.495<sup>grm</sup> = 32.55<sup>ccm</sup>

Analysis showed the following per liter :

|                       |             |
|-----------------------|-------------|
| Ca .....              | 0.600 grams |
| Mg .....              | 0.325       |
| K .....               | 0.019       |
| Na .....              | 0.533       |
| SO <sub>4</sub> ..... | 2.607       |
| Cl .....              | 0.362       |

Qualitative examination showed results similar to those of the water 172 taken near the shore. While the two waters resemble each other as regards the salts present, it will be noted that the shore water contains decidedly more calcium sulphate, but less sodium. The presence of hydrogen sulphide in the water from the middle of the lake is difficult to account for, unless there may be a sulphur spring beneath the lake at this point. The shores of the lake being so largely gypsum, as appears from the specimens, the water near the shore might take up more of this material, accounting for the increased gypsum content of the shore water over that of the middle of the lake.

The gypsum of the lake shore is quite possibly formed from the evaporated lake water. This appears probable from the fact that the gypsum, deposited on evaporating both waters, contains in addition to the ordinary forms a small proportion of crystals similar to those described above in deposit No. 9. If this is the case it would be interesting to know the origin of the large content of gypsum in the lake water. The shore water is evidently a supersaturated solution of gypsum. On the other hand, the lake may obtain its gypsum from the gypsum deposits of the vicinity. The problem must be considered unsolved until further explorations of the lake are made.

Washington and Lee University, Lexington, Va., June, 1896.



ART. LIX.—*A method for the Separation of Aluminum from Iron*; by F. A. GOOCH and F. S. HAVENS.

[Contributions from the Kent Chemical Laboratory of Yale University.—LXI.]

OF the well-known methods for the separation of aluminum from iron—by the action, for example, of an alkaline hydroxide in aqueous solution or by fusion of the mixed oxide in potassium or sodium hydroxide; by reduction of the iron oxide to the metal by heating in hydrogen, with the subsequent solution of the metallic iron in hydrochloric acid; by boiling the nearly neutral solution of the salts of aluminum and iron with sodium thiosulphate either with or without sodium phosphate; by acting with hydrogen sulphide or ammonium sulphide upon solutions of the salts containing also an ammoniacal citrate or tartrate—no single process can be said to be ideal as regards directness, rapidity and accuracy of working. We have deemed it not superfluous, therefore, to attempt the utilization of a reaction which should apparently be capable of effecting directly and quickly the separation of aluminum from iron under conditions easily attainable.

It is known\* that the hydrous aluminum chloride  $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$  is very slightly soluble in strong hydrochloric acid, while ferric chloride, on the other hand, is extremely soluble in that medium. It is this difference of relation of which we wished to take advantage.

It appeared at the outset that crude aluminum chloride could be freed from every trace of a ferric salt by dissolving it in the least possible amount of water, saturating the cooled solution with gaseous hydrochloric acid, filtering upon asbestos in a filtering crucible or cone, and washing the crystalline precipitate with the strongest hydrochloric acid. Aluminum chloride prepared in this way gave no trace of color when dissolved in water and tested with potassium sulphocyanide. The correlative question as to how much aluminum chloride goes into solution under the conditions was settled by taking a portion of the pure aluminum chloride, dissolving it in a very little water, diluting the solution with strong hydrochloric acid, saturating the cooled liquid with the gaseous acid, filtering on asbestos, precipitating by ammonia the aluminum salt in the filtrate and weighing the ignited oxide.

From 10cm<sup>3</sup> of such a filtrate we obtained in two determinations 0.0022 grm. and 0.0024 grm. of the oxide, the mean of which corresponds to 23 parts of the oxide or 109 parts of the hydrous chloride in 100,000 parts of the strong hydrochloric acid. This degree of solubility, though inconsiderable when

\* Gladysz: Ber. d. d. chem. Gesell., xvi, 447.

the objective point is the preparation of the pure salt of aluminum, is obviously incompatible with the attainment of quantitative accuracy in the retention of the aluminum. We have found, however, that various mixtures of anhydrous ether and the strongest hydrochloric acid can be used satisfactorily as solvents for the iron chloride, while the aluminum chloride is insoluble to a very high degree in a mixture of hydrochloric acid and ether taken in equal parts and thoroughly saturated with gaseous hydrochloric acid at the atmospheric temperature. We found that 50 cm<sup>3</sup> of the solution of aluminum chloride, obtained by mixing about 0.1 gm. of the hydrous chloride (dissolved in 2 cm<sup>3</sup> of water) with the mixture of pure, specially prepared aqueous hydrochloric acid and ether in equal parts and again saturating the liquid at 15° C. with gaseous hydrochloric acid, left upon evaporation and ignition 0.0004 gm. in each of two experiments—results which indicate a maximum solubility corresponding to 1 part of the oxide or approximately 5 parts of the chloride in 125,000 parts of the equal mixture of ether and aqueous hydrochloric acid of full strength.

Pure aqueous hydrochloric acid of full strength mixes perfectly with its own volume of anhydrous ether, but it is a curious fact that the addition to this mixture of any very considerable amounts of a solution of ferric chloride in strong hydrochloric acid determines the separation of a greenish oily ethereal solution of the ferric salt upon the surface of the acid. The addition of more aqueous acid does not change the conditions essentially, but more ether renders the acid and the oily solution completely miscible. The ferric chloride seems to abstract ether from the ether-acid mixture and, then dissolved in the ether, remains to some extent immiscible with the aqueous acid thus left until the addition of more ether restores to the mixture that which was taken from it by the ferric chloride. Our experiments show that, while for the separation of insoluble aluminum chloride from certain small amounts of soluble ferric chloride the mixture of the strongest aqueous hydrochloric acid and ether in equal parts serves a most excellent purpose, when larger amounts of ferric chloride are to be dissolved ether must be added proportionately in order to prevent the separation of the ethereal solution of ferric chloride from the rest of the liquid.

Great care was taken to insure the purity of the aluminum chloride used in the test experiments. The so-called pure chloride of commerce was dissolved in the least possible amount of water and this solution was treated with a large volume of strong hydrochloric acid. The chloride thus obtained, free from iron, but possibly contaminated (as we found by expe-

rience) with some alkaline chloride, was dissolved in water and converted by ammonia to the form of the hydroxide, which was thoroughly washed and dissolved in hot hydrochloric acid of half-strength. From this solution, after cooling, gaseous hydrochloric acid precipitated the hydrous chloride in pure condition. The chloride thus prepared was dissolved in water and the strength of the solution was determined by precipitating the hydroxide from definite portions, and weighing the ignited oxide in the usual manner.

TABLE I.

|      | Al <sub>2</sub> O <sub>3</sub> taken in<br>solution as the<br>chloride.<br>gram. | Al <sub>2</sub> O <sub>3</sub><br>found.<br>gram. | Final<br>volume.<br>cm <sup>3</sup> | Error.<br>gram. |
|------|--|---|-------------------------------------|-----------------|
| (1)  | 0.0761   | 0.0746  | 50                                  | 0.0015—         |
| (2)  | 0.0761   | 0.0745  | 50                                  | 0.0016—         |
| (3)  | 0.0761   | 0.0741  | 50                                  | 0.0020—         |
| (4)  | 0.0761   | 0.0734  | 50                                  | 0.0027—         |
| (5)  | 0.0761   | 0.0756  | 50                                  | 0.0005—         |
| (6)  | 0.0157   | 0.0149  | 45                                  | 0.0008—         |
| (7)  | 0.0157   | 0.0147  | 40                                  | 0.0010—         |
| (8)  | 0.0157   | 0.0144  | 45                                  | 0.0013—         |
| (9)  | 0.0480   | 0.0481  | 30                                  | 0.0001+         |
| (10) | 0.0960   | 0.0957  | 30                                  | 0.0003—         |

In the experiments recorded in Table I, measured portions of the standardized solution were submitted to the treatment with hydrochloric acid and ether. The essential thing in the process is to have at the end a mixture of the strongest aqueous hydrochloric acid with an equal volume of anhydrous ether saturated at a temperature of about 15° C. The most convenient way to secure these conditions seems to be to mix the aqueous solution of the aluminum salt with a suitable volume of the strongest aqueous hydrochloric acid—enough to make the entire volume something between 15 and 25 cm<sup>3</sup>—to saturate this mixture with gaseous hydrochloric acid while the liquid is kept cool by immersing the receptacle containing it in a current of running water, to intermix a volume of ether equal to the volume of the liquid, and finally, to treat the ethereal mixture once more with the gaseous acid to insure saturation. The precipitated crystalline chloride was collected upon asbestos in a perforated crucible, washed with a previously prepared mixture of hydrochloric acid and ether carefully saturated with the gaseous acid at 15° C., and either ignited after careful drying at 150° or redissolved in water, converted to the hydroxide by ammonia in the usual way and weighed as the oxide after filtration, washing, and ignition. In experiments (1) to (4) the precipitated chloride was ignited directly; in



experiment (5) the ignition was made with great care in an atmosphere of superheated steam; and in experiments (6) to (10) the chloride was dissolved, precipitated as the hydroxide, and weighed as the oxide.

The experiments in which the chloride was converted to the hydroxide before ignition show upon the average an absolute loss of about 0.0006 grm.; the single experiment in which the ignition took place in steam shows about the same loss—0.0005 grm.; while in those experiments in which the chloride was dried and then ignited directly, the average loss amounts to about 0.0020 grm. The error of the process which involves the precipitation of the aluminum as the hydroxide, falls within reasonable limits, but it is plain that the direct ignition of the chloride is liable to error, which may possibly be explicable as a mechanical loss occasioned by the too rapid evolution of the hydrochloric acid and water of crystallization, or, possibly, as the result of a very slight volatilization of the aluminum still holding chlorine in spite of the decomposing action of the water upon the chloride. In either case, it would seem to be reasonable to suppose that a layer of some easily volatilizable oxidizer placed upon the aluminum chloride might serve to obviate the difficulty—in the one case, by serving as a screen to diminish mechanical transportation of the non-volatile material; and in the other, by acting as an agent to promote the exchange of chlorine for oxygen on the part of the aluminum chloride.

We have tried, therefore, the expedient of covering the aluminum chloride before ignition with a layer of mercuric oxide, which of itself left no appreciable residue when it volatilized. The hydrous chloride was collected as usual upon the asbestos in a perforated crucible, dried for a half-hour at 150° C, covered with about 1 grm. of the pure mercuric oxide, gently heated with great care under a suitable ventilating flue, and finally ignited over the blast. The results are given below:

TABLE II.

|     | Al <sub>2</sub> O <sub>3</sub> taken in<br>solution as the<br>chloride.<br>grm. | Al <sub>2</sub> O <sub>3</sub> found<br>by ignition<br>with HgO.<br>grm. | Final<br>volume.<br>cm <sub>3</sub> | Error.<br>grm. |
|-----|---|--|-------------------------------------|----------------|
| (1) | 0.0761  | 0.0758   | 25                                  | 0.0003—        |
| (2) | 0.0761  | 0.0754   | 25                                  | 0.0007—        |
| (3) | 0.0761  | 0.0751   | 25                                  | 0.0010—        |

It is obvious, therefore, that the precipitation of the crystalline hydrous aluminum chloride from solutions of the pure salt is perfectly feasible and very complete, when effected by aqueous hydrochloric acid and ether thoroughly saturated with

the gaseous acid and kept cool; and that the conversion of the chloride into the weighable form of the oxide is best effected by ignition under a layer of mercuric oxide, or by dissolving it in water and precipitating it as the hydroxide to be afterward washed, dried, and ignited. Of the two methods the former is by far the more convenient.

The precipitation of the aluminum chloride in pure condition from solutions containing ferric chloride ought not, it would seem, to present any difficulty, providing only that the precaution is taken to have present a sufficient excess of ether. The question was put to the test of experiment with the results recorded in Table III.

Measured portions of the standardized solution of aluminum chloride were evaporated nearly to dryness in a platinum dish, an amount of pure ferric chloride equivalent to about 0.15 gm. of the oxide was added in a very little water, 15 cm<sup>3</sup> of the mixture of strong hydrochloric acid and ether in equal parts were introduced, the liquid was saturated at 15° C. with gaseous hydrochloric acid (the dish being held in a convenient device for cooling it by running water), 5 cm<sup>3</sup> more of ether were added to secure complete miscibility of the solutions, and more gas passed to perfect saturation. The aluminum chloride was collected upon asbestos in a perforated crucible, washed with a mixture of ether and aqueous hydrochloric acid thoroughly saturated with the gaseous acid, dried at 150° C. for a half-hour, covered with 1 gm. of pure mercuric oxide, and ignited at first gently and finally over the blast.

TABLE III.

|     | Al <sub>2</sub> O <sub>3</sub> taken in<br>solution as the<br>chloride.<br>gram. | Al <sub>2</sub> O <sub>3</sub> found<br>by ignition<br>with HgO.<br>gram. | Fe <sub>2</sub> O <sub>3</sub><br>present as<br>chloride.<br>gram. | Final<br>volume.<br>cm <sup>3</sup> | Error.<br>gram. |
|-----|--|---|--|-------------------------------------|-----------------|
| (1) | 0.0761   | 0.0757  | 0.15   | 25-30                               | 0.0004—         |
| (2) | 0.0761   | 0.0756  | 0.15   | 25-30                               | 0.0005—         |
| (3) | 0.0761   | 0.0755  | 0.15   | 25-30                               | 0.0006—         |
| (4) | 0.0761   | 0.0755  | 0.15   | 25-30                               | 0.0006—         |

The results show plainly a very satisfactory limit of error.

ART. LX.—*Chemical Composition of Hawaiian Soils and of the Rocks from which they have been derived*; by A. B. LYONS, F.C.S., Honolulu, H. I.

THE relation in chemical composition of soils to the rocks from which they have been definitely derived, can be studied most easily and profitably in a volcanic country, where disintegration of the rock is rapid and is attended with great chemical changes. I wish to present, as briefly as is consistent with clearness, the result of studies in this field which I have had occasion to make during the past two years. The chemical composition of these volcanic soils is peculiarly interesting and full of surprises to one unaccustomed to their vagaries.

The agricultural analysis of a soil is, of course, not exhaustive. The mineral constituents determined are merely those extracted from the finer portion of the soil by the action for a definite time of a specified solvent, generally of hydrochloric acid, of sp. gr. 1.15. The solvent is commonly allowed to act from three to five days. I found by experiment that the boiling acid would extract from the fine soil practically all that is soluble in two hours, except in the case of some of the very new soils, and in the analyses here reported this method of extraction was adopted, except in the first two, where a longer time (three days) was taken. In the estimation of phosphoric acid, however, nitric acid was used as a solvent, according to the usual practice. The residue after treatment with hydrochloric acid was found to consist almost wholly of silica and titanitic acid. It contained little iron, calcium or magnesium, but retained considerable potassium and sodium, sometimes as much as eighty per cent of all present in the soil. These facts must be borne in mind in making comparisons of the soil analyses with the complete and exact analyses I have to report of the rocks from which the soils have been derived.

In order to bring out clearly the comparison between soil and rocks, I have reported the mineral constituents only of the soils in per cent. of the weight of the ignited sample. I have added, however, at the foot of the table figures indicating the percentage loss on drying at 100° C, and further on ignition of the air-dried soil.

Out of a large number of soil analyses I have selected for tabulation some that may be considered representative. The first three are soils derived from decomposition of volcanic sand or ash, spread over the surface of the country by explosive eruptions so recent that only the finer particles have suffered disintegration. These soils are sandy or gravelly, almost



wholly destitute of clay, and contain comparatively little organic matter.\* The mineral constituents requisite for plant food are present in extraordinary abundance, especially the phosphoric acid, and yet these soils may be rather easily "exhausted" by loss of their organic matter.

TABLE I. ANALYSES OF HAWAIIAN SOILS. [MINERAL CONSTITUENTS.\*]

|                                  | New, from lapilli. |                 |                 | New, from lava only partially disintegrated. |               |               |                 | Old, from thoroughly disintegrated ancient lava. |            |              |
|----------------------------------|--------------------|-----------------|-----------------|--|---------------|---------------|-----------------|--|------------|--------------|
|                                  | Punahou, Oahu.     | Pahala, Hawaii. | Waimea, Hawaii. | Molokai, Oahu.**                             | Hilo, Hawaii. | Hilo, Hawaii. | Ookala, Hawaii. | Ewa, Oahu.                                       | Ewa, Oahu. | Manoa, Oahu. |
| Al <sub>2</sub> O <sub>3</sub> † | 22.79              | 12.97           | 23.97           | 23.69  | 22.09         | 17.84         | 23.53           | 27.48  | 29.06      | 26.86        |
| Fe <sub>2</sub> O <sub>3</sub>   | 24.73              | 10.93           | 18.78           | 29.12  | 44.85         | 32.13         | 34.86           | 20.31  | 24.54      | 29.72        |
| MnO                              | .20                | .03             | .29             | .46  | .10           | .29           | .34             | .15  | .11        | .18          |
| CaO                              | 5.47               | 3.44            | 5.70            | .74  | .09           | .41           | .66             | .39  | .38        | .29          |
| MgO                              | 3.62               | .73             | 1.43            | 1.81   | .19           | .61           | 1.07            | .23  | .28        | .74          |
| Na <sub>2</sub> O                | 1.07               | .71             | .19             | 1.07   | .33           | .17           | .33             | .34  | .34        | .22          |
| K <sub>2</sub> O                 | .74                | .19             | .39             | .58  | .21           | .37           | .38             | .51  | .43        | .16          |
| P <sub>2</sub> O <sub>5</sub>    | 2.92§              | .48             | 6.47¶           | .36  | .40           | .49           | .76             | .10  | .15        | .27          |
| SO <sub>3</sub>                  | .18                | .05             | .27             | .10  | .16           | .11           | .49             | .07  | .06        | .08          |
| Soluble SiO <sub>2</sub> , etc.  | 3.23               | 1.68            | 2.43            | { 42.48                                      | 7.20          | 4.69          | 5.45            | { 50.01  | { 44.69    | 5.31         |
| Insoluble                        | 36.20              | 68.79           | 39.72           |  | 24.39         | 42.98         | 33.09           |  |            | 37.24        |
| Organic and combined Water†      | 15.10              | 14.94           | 29.46           | 11.88  | 34.30         | 14.40         | 40.80           | 16.06  | 17.09      | 19.77        |

\* Constituents dissolved by boiling two hours with hydrochloric acid, sp. gr. 1.15.

† Figures except in last line are percentages of the ignited soil.

‡ Per cent. of soil dried at 100° C.

§ Phosphoric acid in soils from this region ranges from 1.2 to 2.9 + % of ignited soil.

¶ Contains much undecomposed silicate.

|| Phosphoric acid in soils from this region ranges from 2.5 to 6.5 per cent. of ignited soil.

\*\* Contains cobalt. Most of the soils contain copper, some of them chromium.

No. 1 is derived from a coarse volcanic gravel (lapilli), thrown out in an eruption so recent that except within a few decimeters of the surface it remains as black and fresh-looking as it ever was. If this soil is passed successively through sieves having respectively apertures 2<sup>mm</sup>, 1<sup>mm</sup> and ½<sup>mm</sup> in diameter, the first will screen out chiefly fragments of undecomposed gravel, while the second and third will retain coarse sand which will be found to consist almost wholly of crystals, mostly superficially oxidized, of chrysolite. A finer, heavy,

\* Owing to the absence of clay, the organic matter present in such soils is liable to be in a remarkable degree combustible.

black sand can be separated by washing, consisting of octohedral crystals, part only of which are magnetic. Under a lens, it will be seen that the crystals of chrysolite are studded also with these iron crystals.

The proportion of phosphoric acid in this soil (nearly three per cent) seems fabulous; what is remarkable is that it is much higher than in any sample I have analyzed of the lapilli whence it was derived.

No. 2 is from a volcanic sand consisting of finer particles, but more resistant to the action of acids, so that the residue on treatment with hydrochloric acid is very large, and obviously retains much base. The chrysolite in this soil is nearly transparent, being scarcely at all oxidized.

No. 3 is an older soil, but derived, I think, from a fine-grained volcanic ash. There is almost no clay, but neither is there much sand. The soil contains few particles exceeding  $0.1^{\text{mm}}$  in diameter; more than half of it is "dust," the particles being less than  $.01^{\text{mm}}$  in diameter. Analysis indicates that it is derived from a highly feldspathic lava. The figure for phosphoric acid will excite incredulity in others as it did in myself until confirmed by duplicate experiment. The quantity varied greatly in samples of the soil taken from different localities, but in all was absurdly high—much in excess of that found in any sample of the country rock.

The next four samples are derived from the decomposition of comparatively recent lava. Most of the arable soil on Hawaii and much of that on Maui belongs to this class. These soils agree in containing, like those of the first class, much unoxidized iron and a large proportion of phosphoric acid (in no case amounting, however, to as much as one per cent). The proportions of calcium and of potassium are generally not very small, but vary greatly with the climate. When the rainfall is not excessive, these bases are present in good, or even in large, proportion; but in rainy regions, as in the Hilo district, they may be greatly reduced, especially the calcium, as illustrated in sample No. 5 in the table. This same sample is remarkable again for its small content of silica and for its exceedingly large proportion of iron.

The soils of the third class, designated "old," are derived from ancient lavas completely disintegrated. They are distinctly clayey, and of a deep red color, containing very little ferrous iron. The proportion of phosphoric acid is generally smaller than in the new soils and calcium is commonly low, but these clayey soils are not as easily exhausted by careless tillage as the others.

Table No. II gives the results of analyses of a series of representative Hawaiian lavas. No. 1 in this series is especially interesting because it is from this material (lapilli) that the

Punahou soil already spoken of has been derived. It is what is familiarly known in Honolulu as "black sand," used as a dressing for driveways and garden walks. It consists of a black, fresh-looking lava in irregular angular fragments, from one to ten or even twenty millimeters in their several dimensions. Spring water that has leached through this black sand

TABLE II. ANALYSES OF HAWAIIAN LAVAS.

|                                | 1.                  | 2.                      | 3.                              | 4.                                | 5.                   | 6.   | 7.                                    | 8.                                    | 9.                                     | Av.   |
|--------------------------------|---------------------|-------------------------|---------------------------------|-----------------------------------|----------------------|--|---------------------------------------|---------------------------------------|--|-------|
|                                | Lapilli.<br>Recent. | Scoriaceous.<br>Recent. | Compact<br>Feldspathic,<br>Old. | Scoriaceous<br>Vesicular,<br>Old. | Porphyritic,<br>Old. | Feldspathic<br>Large Crystals,<br>Ancient. | Compact,<br>Ancient.                  | Somewhat<br>Vesicular,<br>Ancient.    | Capillary<br>"Pete's hair,"<br>Recent. |       |
|                                | Punahou,<br>Oahu.   | Punahou,<br>Oahu.       | Waimea,<br>Hawaii.              | Waimea,<br>Hawaii.                | Kohala,<br>Hawaii.   | Waianae,<br>Oahu.                          | Waianae,<br>Oahu.                     | Waimea,<br>Oahu.                      | Kilauea,<br>Hawaii.                    |       |
| SiO <sub>2</sub>               | 35.86               | 36.85                   | 58.06                           | 47.33                             | 49.01                | 46.30                                      | 51.63                                 | 49.88                                 | 45.79                                  | 47.86 |
| TiO <sub>2</sub>               | 2.90                | 4.05                    | 1.88                            | 4.84                              | 3.93                 | 5.35                                       | 2.47                                  | 3.97                                  | 3.25                                   | 3.63  |
| Al <sub>2</sub> O <sub>3</sub> | 12.10               | 11.97                   | 18.21                           | 17.96                             | 16.29                | 17.95                                      | 12.10                                 | 13.79                                 | 15.09                                  | 15.05 |
| Fe <sub>2</sub> O <sub>3</sub> | 7.82                | 13.90                   | 4.87                            | 12.64                             | 7.61                 | 6.21                                       | 8.67                                  | 9.65                                  | 5.34                                   | 8.59  |
| FeO                            | 8.09                | 6.54                    | 2.01                            | .51                               | 4.89                 | 6.79                                       | 3.10                                  | 2.61                                  | 5.58                                   | 4.46  |
| MnO                            | .39                 | 1.13                    | .36                             | .64                               | .27                  | .26  | .30                                   | .67                                   | .49                                    | .50   |
| CaO                            | 12.08               | 9.00                    | 3.29                            | 6.29                              | 9.79                 | 8.17                                       | 9.17                                  | 9.59                                  | 10.21                                  | 8.62  |
| MgO                            | 9.72                | 10.73                   | 1.59                            | 3.97                              | 3.62                 | 3.67                                       | 9.40                                  | 6.12                                  | 5.92                                   | 6.08  |
| Na <sub>2</sub> O              | 6.23                | 4.13                    | 6.12                            | 3.67                              | 3.82                 | 3.92                                       | 3.10                                  | 3.30                                  | 3.67                                   | 4.22  |
| K <sub>2</sub> O               | 1.93                | .79                     | 2.75                            | 1.10                              | .80                  | .89  | .30                                   | .17                                   | .90                                    | 1.07  |
| CuO                            | .25                 | .10                     | .10                             | .15                               | .10                  | .17  | .48                                   | .14                                   | .18                                    | .19   |
| P <sub>2</sub> O <sub>5</sub>  | 1.08                | 1.25                    | .65                             | 1.05                              | .49                  | .53  | .26                                   | .26                                   | .29                                    | .65   |
| SO <sub>3</sub>                | .27                 | tr.                     | .05                             | .07                               | .20                  | .06  | .07                                   | .09                                   | 2.54†                                  | .10   |
| S                              |                     | .14                     | .05                             | .07                               | .02                  | .05  | .03                                   | .02                                   |  | .11   |
|                                | FeS<br>1.40         | CoO<br>.04              |                                 |                                   |                      |  | Cr <sub>2</sub> O <sub>3</sub><br>tr. | Cr <sub>2</sub> O <sub>3</sub><br>tr. |  |       |
| Total                          | 100.12              | 100.62                  | 99.99                           | 100.29                            | 100.84               | 100.32                                     | 101.08                                | 100.26                                | 99.25                                  |       |
| Dried* at<br>100°, C.          |                     | 5.48                    | .53                             | 2.38                              | .98                  | 1.75                                       | .47                                   | 1.84                                  |  |       |
| Ignited †                      |                     | 4.74                    | .83                             | 3.08                              | 1.00                 | 2.00                                       | .33                                   | 1.14                                  |  |       |

\* Percentage loss of original air dried powder.

† Additional percentage loss of original powder on ignition.

‡ Derived from exposure to sulphurous fumes, and hence not considered in the averaging.

is charged with sodium carbonate. Acids act very vigorously on the sand, generating much heat and rapidly disintegrating the mineral, with separation of gelatinous silica and evolution of hydrogen sulphide. The lava is evidently an exceedingly basic one, and it is to be observed that it comes from the most



recent eruption of an extinct volcano, whose older lavas are distinctly less basic. The volcano must have been for many ages wholly extinct previous to the period of activity during which this black sand was ejected, in a stupendous explosive eruption, which spread it over an area many square miles in extent, in a stratum from one to fifty meters or more in depth.

The points of interest in the composition of this lava are its low content of silica and the very large proportion it contains of ferrous iron, of unoxidized sulphur and of phosphoric acid.

No. 2 is lava from a cinder cone at the base of the volcano from which the black sand was ejected. The black sand overlies this lava at some points, but I believe that they belong to the same period of volcanic activity, so recent that even in exposed situations the wrinkles and creases, formed while the lava was in a pasty condition as it cooled, remain as sharply defined as ever. The chemical composition agrees in the main with that of No. 1, the differences being, in part, what we might expect from differences in the circumstances of the respective eruptions. Unoxidized sulphur has nearly disappeared, and the proportion of ferrous iron has been greatly reduced, by prolonged exposure of the fluid lava to the air. There are, however, interesting differences in the original composition of these two products of a single volcano, the explanation of which is beyond the scope of the present paper.

The presence in notable quantity of cobalt, and the extraordinarily large proportion of manganese and of phosphoric acid are the points of especial interest. Lavas from Telegraph Hill, three miles distant, nearly or quite as recent, exhibit the same peculiarities in chemical composition. In both localities, incrustations of manganese dioxide occur on rocks that have been submerged.

In No. 3 we have a lava of a totally different character. It is a bluish gray, compact, minutely crystalline lava, containing much feldspar and very little chrysolite, and is the prevailing rock in the Kohala mountain, at least in the Waimea neighborhood. It seems to be similar to the lavas sent to Prof. Dana by Rev. S. E. Bishop, from West Maui, and differs from all other Hawaiian lavas I have analyzed in its small content of iron and of titanite acid.

No. 4 is a highly vesicular, red lava from the ejecta of one of the numerous cinder cones on the Kohala mountain. Here again, in a more recent lava, we find the proportion of bases and that of phosphoric acid increased. It seems probable that the soil No. 3 originated from volcanic ash ejected from these same cinder cones, the proportion of phosphoric acid being there still higher.

No. 5 is also a lava from the Kohala mountain (the oldest of the Hawaii mountains, but recent in comparison with the

mountains of Oahu); a somewhat vesicular stony lava of rather light color, porphyritic with white crystals of feldspar.

No. 6 is a type which I have seen nowhere but on the island of Oahu, and chiefly in the oldest formations of that island, viz: in the Waianae mountains. I should expect to find it also on Kauai, but that island I have not explored. It is highly feldspathic and made up largely of tabular crystals 5 to 15<sup>mm</sup> long and perhaps 1 or 2<sup>mm</sup> thick. In superficial portions of the rock, the augitic constituent of the lava is often partially disintegrated, but the specimen analyzed was quite sound. It is especially remarkable for the large proportion it contains of titanitic acid. Previous analyses of Hawaiian lavas, I may remark, seem not to have given due attention to this constituent, which in some of them is not even mentioned.

No. 7 is a close-grained dark basalt with a few green crystals of chrysolite, from one of the oldest formations of Oahu. Although taken from a fragment that had been detached from the cliff and had lain for ages where it was submerged at spring tide with salt water, it seemed to have suffered absolutely no change, except superficially, and it may be regarded as a representative specimen of this ancient trap-like basalt. Copper, which is present in all the Hawaiian lavas examined, reaches in this a maximum figure—nearly half of one per cent of CuO.

No. 8 is another representative sample from the lowest beds of the Koolau range of Oahu. It is somewhat vesicular, and has suffered some change probably in the oxidation of a portion of its ferrous iron, and possibly in the loss of some of its potash—I think not to any great extent. This, as well as the preceding specimen, contains chromium, which may have been present in traces in some of the other lavas, as it is not unfrequently present in the Hawaiian soils.

No. 9 is the capillary form of lava known as *Pele's hair*. Of course it is simply the lava of Kilauea spun into fine threads and so instantaneously cooled. The sample analyzed was, however, not a representative one, for it had been a long time exposed to the sulphurous vapors from Halemaumau, the result appearing in the analysis in its extraordinary content of sulphate. We call to mind in this connection the incrustations, about fissures in Kilauea, of ferric sulphate, and the stalactitic deposits of sulphates of soda, calcium, aluminum and even of copper (curiously enough not often of iron) found in caverns in the crater.

Table III gives the result of analyses of specimens of rock altered by exposure to the weather, and of volcanic tufa. In the former, while titanitic acid seems to have been but slightly diminished in amount, there has been a notable loss of silica,

and calcium, magnesium, sodium and potassium have almost wholly disappeared.

TABLE III. ANALYSES OF HAWAIIAN ROCKS, ETC.

|                                | "Rotten" Lava.     |                   |                 |       | Tufa.               |                           |                     |       | Sound Lavas.<br>Av. | Mineral of Soils.<br>Av. |
|--------------------------------|--------------------|-------------------|-----------------|-------|---------------------|---------------------------|---------------------|-------|---------------------|--------------------------|
|                                | I.                 | II.               | III.            |       | I.                  | II.                       | III.                |       |                     |                          |
|                                | Honolulu,<br>Oahu. | Kaneohe,<br>Oahu. | Hilo<br>Hawaii. | Av.   | Punchbowl,<br>Oahu. | Diamond<br>Head,<br>Oahu. | Salt Lake,<br>Oahu. | Av.   |                     |                          |
| SiO <sub>2</sub>               | 34.81              | 4.54              | 24.62           | 21.32 | 37.82               | 40.11                     | 47.44               | 41.79 | 47.86               | } 40.00                  |
| TiO <sub>2</sub>               | 4.89               | 8.99              | 8.12            | 7.33  |                     |                           |                     |       | 3.63                |                          |
| Al <sub>2</sub> O <sub>3</sub> | 33.18              | 41.35             | 23.89           | 32.81 | 13.16               | 12.40                     | 16.51               | 14.02 | 15.05               | } 22.59                  |
| Fe <sub>2</sub> O <sub>3</sub> | 23.03              | 40.87             | 37.85           | 33.92 | 14.11               | 14.64                     | 15.33               | 14.69 | 8.59                |                          |
| FeO                            | 2.34               | 2.52              | 2.08            | 2.31  | .14                 | tr.                       | 3.19                | 1.11  | 4.46                | } 30.05                  |
| MnO                            | .28                | .08               | .25             | .30   | .24                 | .25                       | .37                 | .29   | .50                 |                          |
| CaO                            | tr.                | tr.               | tr.             | tr.   | 13.39               | 12.24                     | 6.02                | 10.55 | 8.62                | 1.26                     |
| MgO                            | .39                | .37               | .99             | .58   | 11.75               | 11.65                     | 8.80                | 10.73 | 6.08                | 1.19                     |
| Na <sub>2</sub> O              | tr.                | tr.               | 1.41            | .47   | 1.66                | 2.72                      | 1.60                | 1.99  | 4.22                | .50                      |
| K <sub>2</sub> O               | tr.                | tr.               | tr.             | tr.   | 1.49                | .96                       | .30                 | .91   | 1.07                | .43                      |
| CuO                            | .37                | .26               | .27             | .30   | .07                 | .11                       | .08                 | .09   | .19                 |                          |
| P <sub>2</sub> O <sub>5</sub>  | .39                | .63               | .24             | .42   | .82                 | .57                       | .61                 | .67   | .65                 | .68                      |
| SO <sub>3</sub>                | .31                | .55               | .40             | .42   | .15                 | .17                       | .06                 | .13   | .10                 | .22                      |
| CO <sub>2</sub>                |                    |                   |                 | .00   | 5.56                | 4.15                      | .17                 | 3.29  | .00                 | .00                      |
|                                |                    |                   |                 |       | FeS <sub>2</sub>    |                           |                     |       |                     |                          |
|                                |                    |                   |                 |       | .05                 |                           |                     |       |                     |                          |
| Total                          | 99.99              | 100.16            | 100.12          |       | 100.41              | 99.97                     | 100.48              |       |                     |                          |
| Dried* at 100° C.              | 6.43               | 3.55              | 8.49            |       | 9.98                | 5.46                      | 9.08                |       |                     |                          |
| Ignited†                       | 11.63              | 20.48             | 12.70           |       | 8.24                | 6.48                      | 5.04                |       |                     |                          |

\* Percentage loss of original air dried powder.

† Additional percentage loss of original powder on ignition.

The second sample is the most remarkable. Although it retains the form of the original lava, which was evidently a basalt with distinctly columnar structure, it has changed to an ochre-colored substance that seems almost light enough to float in water, and is as friable as bath brick. Its composition is remarkable, and especially instructive if it should prove, as is probable, that this rock has been subject to the prolonged action of sea water. It consists mostly of alumina and ferric oxide, with nearly nine per cent of titanitic acid and only half that quantity of silica.

The tufas consist essentially of fragments of lava more or less changed by weathering, so that the color is generally of a rusty brown, sometimes mottled with white or with various colors according to the nature of the included particles. Small crystals, or fragments of crystals, of chrysolite are often to be



seen; occasionally there are masses, two to eight centimeters or more, in diameter of such crystals, and similar aggregations sometimes of augite crystals. [These aggregations of crystals are found, I believe, only in the tufa from the Salt Lake region.] The fissures through which the materials of these tufas were ejected, opened through the coral reef formation, and so the tufa contains fragments of the coral rocks from the size of a pin's head to that of a goose egg. The mingled steam and carbonic acid forced up through the magma from which the tufa consolidated, dissolved much of the lime of this coral rock, depositing it again, partly in finely divided state mingled with the mud in its superficial portions, chiefly in crusts on the surface, or in veins occupying fissures in the already consolidated rock. In the tufa of Punchbowl, No. 1, this calcium carbonate has assumed a crystalline form, not only in the joints of the tufa, but penetrating its substance throughout. The regular calcite cleavage planes can be distinctly seen on surfaces of fracture, although the calcium carbonate amounts to no more than five to ten per cent of the rock.

TABLE IV. COMPARISONS.

|                                    | Sound<br>Lava.<br>Av. | Tufa.<br>Av. | "Rotten"<br>Lava.<br>Av. | Soil.<br>Av. | Punahou<br>Rock. | Punahou<br>Soil. |
|------------------------------------|-----------------------|--------------|--------------------------|--------------|------------------|------------------|
| SiO <sub>2</sub>                   | 1680                  | 1393         | 320                      | } 800§       | 1201             | } 811§           |
| TiO <sub>2</sub>                   | 128                   |              | 110                      |              | 97               |                  |
| Al <sub>2</sub> O <sub>3</sub> } * | 1000                  | 1000         | 1000                     | 1000         | 1000             | 1000             |
| Fe <sub>2</sub> O <sub>3</sub> }   |                       |              |                          |              |                  |                  |
| FeO†                               | (156)                 | (37)         | (35)                     | not estim.   |                  |                  |
| MnO                                | 18                    | 10           | 5                        | 4            | 13               | 5                |
| CaO                                | 303                   | 352‡         |                          | 22           | 404              | 118              |
| MgO                                | 213                   | 358          | 9                        | 20           | 324              | 71               |
| Na <sub>2</sub> O                  | 148                   | 66           | 7                        | (9)¶         | 208              | (24)¶            |
| K <sub>2</sub> O                   | 37                    | 30           |                          | (8)¶         | 63               | (15)¶            |
| CuO                                | 7                     | 3            | 5                        | not estim.   | 8                | not estim.       |
| P <sub>2</sub> O <sub>5</sub>      | 23                    | 23           | 6                        | 12¶¶         | 37               | 49               |
| SO <sub>3</sub>                    | 4                     | 4            | 6                        | 4            | 9                | 4                |

\* The Fe<sub>2</sub>O<sub>3</sub> includes total iron present.

† Representing ferrous iron.

‡ If the calcium present as carbonate (coral reef rock) be deducted, this figure would be about 338.

§ Insoluble residue, almost wholly SiO<sub>2</sub> and TiO<sub>2</sub>.

¶ Na<sub>2</sub>O and K<sub>2</sub>O dissolved by boiling hydrochloric acid; the soil generally contains a much larger amount, in the form of insoluble silicates.

¶¶ In soils found from lapilli, the phosphoric acid is generally at least as high as in the lapilli, illustrated in the Punahou soil in the table.

Table IV sums up the conclusions to be drawn from these analyses. Since the alumina and iron together constitute a tolerably constant factor in the composition of the lava, and are not liable to be dissolved out in appreciable quantity within

the time covered by the history of these rocks, I have made these jointly a basis of comparison, to bring out the nature of the changes that have taken place in the weathering of the lava and its conversion into soil. While generalizations cannot be based too confidently on the results of so small a number of analyses, I believe that the data are sufficient to yield us some quite definite and positive conclusions. The validity of the general conclusions is confirmed by the specific example given in the last two columns, where analysis has been made of the identical rock from which the sample of soil has been derived.

We see then that, in the incipient weathering of lava that we find in volcanic tufa (which consists of lava fragments *plus* calcium and magnesium carbonates, and some clay and sea sand), that there has been a notable reduction of silica (17 per cent), titanic acid (practically all), manganese (44 per cent), soda (55 per cent), potash (19 per cent), copper (60 per cent), while calcium remains unchanged and magnesium seems actually to have been increased. [This may have come from the sea water.] There has been, moreover, an oxidation of three-fourths of the ferrous iron.

In the "rotted" lava, there has been a loss of more than 80 per cent of the silica, while titanic acid has been but slightly reduced. [If we omit from the comparison sample No. 2 of the rotted lavas of Table III, the loss of silica would be less considerable, that of titanic acid greater.] There has been a loss of manganese (72 per cent), magnesia (96 per cent), soda (95 per cent), copper (30 per cent), and phosphoric acid (74 per cent), while lime and potash have almost wholly disappeared. Sulphates, on the other hand, appear to have increased, but possibly this would not prove generally true.

In the soil, we find a loss of more than half the silica, 77 per cent of the manganese, 93 per cent of the lime, 91 per cent of the magnesia, and about 50 per cent of the phosphoric acid. Sodium and potassium are largely diminished, but not to the extent indicated in the table, since these bases are only partially extracted by hydrochloric acid. In soils like that of Punahou, formed from lapilli in which the original material is as yet only partially disintegrated, there may be an actual increase in the proportion of phosphoric acid. In the Punahou soil the reduction of silica amounts to only 32 per cent, of manganese to 61 per cent, lime to 72 per cent, magnesia to 78 per cent and sulphuric acid to 55 per cent.

It is especially interesting to note that while the rotted lava has lost positively nearly all its calcium and potassium, the soil retains a considerable proportion of both these elements, a result to be attributed, in part at least, to the influence of plants and, in the case of calcium, of molluscous animals.

ART. LXI.—*The Original Trenton Rocks*; by THEODORE G. WHITE.

["The Faunas of the Upper Ordovician Strata at Trenton Falls, Oneida Co., N. Y." Trans. N. Y. Acad. Sci., xv, 71-96, Pls. II-V.—Author's abstract.]

THIS study is preliminary to a paper by the writer on the Trenton formation in the Lake Champlain valley, in connection with which it was desirable to have a detailed description of the type Trenton Falls section for comparison. As no such tabulation had been published, nor even a statement of the local geological boundaries of the original section, the writer was obliged to go into the field for himself and the results embraced in this paper were obtained.

The type section extends from the bridge just below the mill dam at Trenton Falls village to the bridge at Prospect, about two and a quarter miles along the gorge of West Canada creek. In this distance the creek makes a total fall of over 312 feet. The dip of the strata is in the direction of the current and averages less than 10°. Both above and below the gorge in which the type section occurs, the strata are obscured by heavy drift deposits, so that the beds adjacent to those outcropping in the gorge cannot be determined. Utica shale is not found nearer than Nine Mile Creek, East Trenton, where it is apparently faulted against the Trenton. The shaly layers which form the transition to the Utica in other localities are not represented, but presumably follow the coarse crystalline limestone at the top of the gorge. The 325 feet of strata embraced in the Trenton Falls section seem to include the middle and the beginning of the upper part of the series of strata comprised in the Trenton formation. They apparently indicate a prolonged period during which there were frequent oscillations of the land level, and consequently variable deposition, the waters at first rendered impure by silts but finally clearing and furnishing large accumulations of purely fragmentary remains. In general the lower part of the formation, as seen in the type section, is mostly shaly and is inclined to be nodular, but the limestone increases in purity and becomes crystalline in the higher layers. With the exception of the gray crystalline beds at the top of the mass, the layers rarely exceed one foot in thickness, and are usually two to six inches thick, separated by more shaly layers. There are, however, occasional conspicuous seams of compact blue-black limestone, several feet thick, which continue very constant and hence afford excellent datum levels in measuring the section. From these heavy beds the best specimens of *Asaphus* are obtained,



usually found lying with the ventral surface uppermost. Each layer was separately measured and liberally sampled, and the successive faunal lists, measurements, and descriptions of the lithologic variations of the limestone are enumerated in the paper. The total thickness of the Trenton Falls section thus obtained is 325 feet. Of this, the upper twenty feet consists of heavy-bedded, light gray, coarsely crystalline limestone, very pure, and composed of comminuted fragments in which few species can be recognized. The beds are separated by slightly bituminous thin shaly partings, like the similar strata near Montreal, Canada, and these contain numerous remains, especially crinoids and *Acidaspis Trentonensis*,—the latter not seen lower in the mass.

The lower strata of the Trenton formation are not seen at Trenton Falls, and following down stream, no outcrop of any considerable thickness is found until Rathbone Brook is reached,  $3\frac{1}{2}$  miles below Poland, where a section of over 137 feet is afforded in the bed of the brook. Here the limestone is thin-bedded but shows more distinctly marked zones than at Trenton Falls; is light colored, and frequently sandy in texture. A short distance north of where the brook enters West Canada Creek, an outcrop on the edge of the creek yields a section of Calceferous, Birdseye and Black River, respectively 8,  $9\frac{1}{2}$  and  $11\frac{3}{4}$  feet in thickness. The Chazy is lacking, apparently through non-deposition. The Black River is barren at the base, but above contains abundant *Illænus crassicauda*, *Leperditia fabulites*, *Avicula trentonensis*, *Raphistoma americana*, *Cypricardites obtusus* and *C. ventricosus*, *Zygospira recurvirostra*, *Strophomena filitexta*, *Rhynchotrema inæquivalvis*, *Bathyurus extans*, *Cyrtoceras tenuistriatus*, etc., twenty-six species being noted in all.

In both sections of the Trenton, the fossiliferous portions tend to occur in lenticles, sometimes composed entirely of fragments of one or two species. *Orthis testudinaria*, always abundant, frequently occurs in this way. The transition between the light colored fossiliferous lenticles and the dark compact limestones is often very abruptly marked, the lenticles evidently resulting from depressions filled with fragments in an otherwise even surface of the finest carbonaceous lime sediments. Several well characterized zones occur, but specialized faunal zones are not frequent. In the Rathbone Brook series *Prasopora* of a large tubed variety and *Stenopora fibrosum* are especially abundant in the lower 30 feet. *Holopea symmetrica* and *Trematis terminalis* are rather abundant at from 15 to 30 feet above the base of the section. *Conularia trentonensis* is first found at 30 to 50 feet. *Parastrophia hemipliata*, which occurs just above the top of the Black River at

Watertown, N. Y., and on Lake Champlain, was found here at about 55 feet. In the Trenton Falls section *Orthoceras* and Crinoid fragments are most abundant in the lower portion. *Tellinomya dubia* marks a zone at 18 feet, *Bucania punctifrons* at 40 feet, while at 235 feet is a zone notable for its numerous well-preserved examples of *Rafinesquina deltoidea*. A limestone resembling a cement rock, with graptolites, *Conularia* and *Ambonychia bellistriata*, occurs at 139 feet. Seventy-nine species are recorded in all in the faunal lists of the various beds. *Platystrophia biforata*, *Rafinesquina alternata*, *Plectambonites sericea*, *Asaphus platycephalus*, *Calymene senaria*, and *Ceraurus pleurexanthemus* are prevalent throughout the section. *Rhynchotrema inaequalvis*, *Bellerophon bilobatus*, *Nucula levata*, *Murchisonia gracilis*, and *M. milleri*, and *Trinucleus concentricus* occur principally in the lower layers. In the more shaly layers, various species of *Lingula* occur throughout, and one apparently new species was discovered. *Trematis* seems to be confined to the lower strata, while *Crania trentonensis* first appears toward the top. Various typical Trenton species of frequent occurrence in other localities, such as *Climacograptus*, *Solenopora compacta*, *Orthis occidentalis*, *O. tricenaria*, *O. subquadrata*, *Leptæna rhomboidalis*, *Rhynchotrema capax*, *Cyclospira bisulcata*, were not found among the material collected, indicating that they are at least not abundant, if indeed they occur in the region.

The relative position in the stratigraphy of all the genera previously mentioned has been found in general to be similar in the Lake Champlain valley, and the species lacking at Trenton Falls are lacking there also, apparently indicating comparatively uniform life distribution around the Adirondack island during the period of Trenton seas.

Geological Department, Columbia University.

ART. LXII.—*The Jurassic Formation on the Atlantic Coast* ;\*  
by O. C. MARSH.

THE absence of all Jurassic strata in the eastern part of the United States has been generally regarded as a settled point in geology for half a century or more. The reason for this vacancy has also been one of the problems geologists have had to deal with, since the formations above and below are well represented. Until a comparatively modern date, this supposed absence of Jurassic deposits was thought to be true, also, for the rest of this country. I well remember the parting advice given me by an eminent professor of geology with whom I studied in Germany.† “The first thing you should do on your return to America is,—look for the Jurassic formation. I am sure it is there, full of fossils.” This advice I followed, and on my first visit to the Rocky Mountains, in 1868, I found this formation near Lake Como, Wyoming, well developed, and containing an abundance of typical fossils. As this locality is now a famous one, I have brought here a colored drawing that shows the characteristic variegated strata of the Como Bluff, from which so many remains of Jurassic vertebrates have been taken during my long explorations there.

The base of this section is a red sandstone, apparently of Triassic age. Next above are Jurassic marine beds, with many invertebrate fossils and a few remains of reptiles. Over these beds is a series of peculiar, highly colored clays of fresh-water origin and considerable thickness, rich in vertebrate fossils. Crowning all is the characteristic Dakota sandstone, generally considered of Cretaceous age. The position of this series of strata in the geological scale is shown in the section below, which represents especially the succession of vertebrate life in the West during Mesozoic and Cenozoic time.

*The Baptanodon Beds.*

The same marine beds that constitute the base of the Como Jurassic series, Meek had previously identified near the Black Hills, by means of invertebrate fossils (*Proc. Acad. Nat. Sci., Phila.*, vol. x, pp. 41–59, 1859). I found these deposits again in 1870, near the Green River in Utah, and since then at various other points. These strata I have named the Baptanodon beds, from a genus of large swimming reptiles entombed in them.

\* Abstract of Communication made to the National Academy of Sciences, New York meeting, November 18, 1896.

† Ferdinand Roemer, whose researches here had already added much to our knowledge of the geology and paleontology of this country.





The main physical features of the Jurassic strata in the West, especially the variegated fresh-water deposits, are so striking that, once seen, they will not soon be forgotten. As these physical characters may be used as one means of readily identifying this horizon, I have brought here, besides the colored drawing of the Como section in Wyoming, two others illustrating sections in Colorado. One is from Morrison, near Denver, and the other one hundred miles further south, near Cañon City, both representing, in the *Atlantosaurus* beds, localities famous for the vertebrate fossils they have furnished. I know of no other geological horizon in the West marked by such striking and characteristic physical features.

#### *The Pleurocoelus Beds.*

In the East, the strata most resembling the *Atlantosaurus* beds in physical characters are the Potomac clays and sands so conspicuous between Washington and Baltimore, and known to extend, also, both to the north and south. Although fifteen hundred miles to the eastward, these Maryland strata so strongly recalled those I had explored at the base of the Rocky Mountains, I felt reasonably sure, even before I had examined them, that this series would turn out to be essentially the same age as the *Atlantosaurus* beds of the West. This proved to be the case. Although the Potomac beds have been generally regarded as Cretaceous, I can now safely say that the vertebrate fossils I have secured from them, especially the *Sauropoda*, demonstrate their Jurassic age beyond reasonable doubt. I stated this conclusion in my first description of Potomac fossils, and it is now fully confirmed by more recent discoveries.\*

The fact that the *Sauropoda* of the Potomac beds are all of diminutive size, in comparison with the western forms, is a point of some importance in estimating the age of the strata that contain them. It is a rule almost without exception, that the earlier members of an order of ancient vertebrate animals are small, while the last survivors before extinction are the largest. The gigantic forms of every such group left no successors. Hence, the small *Pleurocelidæ* of the East may possibly be the ancestors of the huge western *Atlantosauridæ*, but can hardly be their descendants. The other vertebrate fossils from the Potomac of Maryland, although fragmentary, all appear to be Jurassic in type.

\* This Journal, vol. xxxv, p. 90, 1888. See also, Sixteenth Annual Report, U. S. Geol. Survey, Part I, p. 183, 1896.

It cannot, of course, be positively asserted at present that the entire series now known as Potomac is all Jurassic, or represents the whole Jurassic. The Lias appears to be wanting, and some of the upper strata may possibly prove to belong to the Dakota.

The latter formation in the West often lies apparently conformably on the *Atlantosaurus* beds, and besides its many fossil plants contains fragments of bones, but these may have washed out of the Jurassic clays below. Footprints resembling those of birds have also been found.

#### *The Potomac Formation.*

The Maryland Potomac, as we know it to-day, is the keystone to the arch. If this is Jurassic, as now seems certain, it is a fair conclusion that the same series of deposits, north and south, are essentially of the same age. The only region along this line of a thousand miles or more, where a systematic search for vertebrate fossils has been made, is in Maryland, and here a rich fauna has been found. Doubtless in many outcrops of this formation, animal remains may be rare or absent, as they appear to be in the Triassic below, but vertebrate life we know was abundant during the Jurassic, and characteristic remains will sooner or later come to light.

Taking, then, the Potomac formation as it is developed in Maryland as an eastern representative of the Jurassic, let us see what follows. The authorities on this formation—McGee, Ward, Fontaine, Uhler, and others, agree that it extends south along the Atlantic border as far as North Carolina, holding the same relative position, and the same general characteristics. That it also extends west around the Gulf border has been asserted by those most familiar with its southern development, but on this point I cannot speak from personal observation.

From the Potomac River northward, however, I have made sufficient explorations along its outcrops through Maryland, Delaware, and Pennsylvania, to the Delaware River, to ascertain its distinctive features, essentially the same throughout, with its geological position still maintained. In New Jersey, I have likewise followed its equivalent strata across the state in the great series of variegated plastic clays, to the Raritan River, and again in their exposure on Staten Island, everywhere seemingly the same series of strata and of the same age. The position is a definite one, always along the line where the Jurassic must lie, if present.

Along the northern shore of Long Island, the same formation extends, and at many outcrops it may be seen with its characteristic features well displayed. I have recently examined these exposures at many points, and all tell the same story. At Montauk Point and on Gardiner's Island, I found apparently the same deposits, but with local variations that need not now be discussed.



Block Island, evidently once a part of Long Island, I have also examined. Its basal clays agree in most respects with the above representatives of the same horizon, as I have shown elsewhere.\*

### *Gay Head.*

By far the finest exhibition of the great formation in question may be seen on Martha's Vineyard, especially at Gay Head, which for a century has attracted the attention of geologists, who have tried in vain to solve its mysteries. My first visit to this classic region was in September last, and I know of no point on the Atlantic coast, from Nova Scotia to Florida, of more interest to geologists. The striking resemblance between the variegated cliffs at Gay Head, the Potomac hills in Maryland, and Como bluffs in Wyoming, will impress everyone who has seen them. That all three are of essentially the same geological age, I have good reason to believe. Two of them are certainly Jurassic, as demonstrated by typical vertebrate fossils, and I hope soon to prove that Gay Head, so similar in all other respects, also contains the same characteristic vertebrate fauna that marks the Jurassic,—the long missing formation on the Atlantic coast.

It has already been shown that the vertebrate fossils of the Potomac in Maryland prove its age there to be Jurassic, especially when taken in connection with the rich fauna of the *Atlantosaurus* beds of the West. In determining the age of the whole series, every aid that paleontology can render should be brought to bear upon the question, but a discrimination greater than has hitherto been shown is necessary to secure the best results.

In addition, then, to the evidence of vertebrate fossils as to the age of this eastern formation, the testimony of the invertebrates and plants should also be considered. The invertebrates known from these strata are few in number, but some of the mollusks among them point to the Jurassic age, as Whitfield has shown.† Nearly all, however, were estuary or fresh-water forms, which are now generally admitted to be of slight value as witnesses of geological changes.

### *Evidence of Fossil Plants.*

Remains of plants are numerous, but usually fragmentary, and these have been collected at many localities, and studied by botanists of much experience in such investigations. The verdict they have rendered has not been a unanimous one, but is especially interesting, as it coincides at one point with the decisions some of their predecessors have rendered as to the age of other geological horizons in the succeeding formations of the West.

\* This Journal, vol. ii, p. 295, October, and p. 375, November, 1896. In the second paper will be found an abstract of the more important literature.

† Monograph IX, U. S. Geol. Survey, p. 23, 1885.

The horizons I especially refer to are in the Dakota, Laramie, and Eocene, all essentially of lacustrine origin, and now well known. Fossil plants in good preservation have been collected in each of these in turn, and pronounced by eminent botanists to be Miocene. Other paleobotanists of equal eminence have reviewed the evidence and made the age somewhat older, but, as a rule, the conclusion reached made the deposits in question at least one period later than the animal remains indicated. To explain this discordance, it was in one case gravely asserted that a Cretaceous vertebrate fauna lived in the midst of a Tertiary flora. A larger knowledge of the facts has since led to revision of the first opinions on this point, and the Cretaceous age of both is now admitted.

It seems to me extremely probable that in the Potomac formation we again have an analogous case. The botanists have pronounced the plants Cretaceous, while the vertebrates are certainly Jurassic. Change the botanical scale one notch, as was done in the horizons above, and the flora and fauna agree, while the Jurassic formation, so long missing, is in its proper place on the Atlantic coast as it is in the West. The North American botanical timepiece was originally set by the European clock, which was one period too slow, as many facts now indicate. Sooner or later, an adjustment must be made.

#### *Age of the Wealden.*

To illustrate this, I may mention, as the latest change in the European time-standard, the Wealden formation, the Cretaceous age of which has long been considered a settled point. I had studied this formation at many localities in England and on the continent, as it contained a reptilian fauna similar to one I had found in the Rocky Mountains, and regarded as Jurassic. A further study of the Wealden reptiles caused me to question their Cretaceous age, and a comparison of these with allied forms from the Rocky Mountains led me to the conclusion that both series were Jurassic.

At the meeting of the British Association, at Ipswich, last year, I read a paper on European Dinosaurs, including two from the Wealden, and thus the question of their geological age came up for determination. The facts I presented, based mainly upon the reptilian fauna, strongly indicated the Jurassic age of the Wealden, and I urged a re-examination of the question by English geologists.\* The subject has since been taken up by Smith Woodward, with special reference to the fossil fishes, on which he is high authority. In the Geological Magazine for February, 1896, he gives the main results of his investigation, which prove that the fishes, also, of the Wealden are of Jurassic types, thus placing the geological age of this formation beyond reasonable doubt.

\* Report, British Association for the Advancement of Science, p. 688, 1895; and this Journal, vol. 1, p. 412, November, 1895.

The same conclusion, based upon a review of the Wealden plants, has recently been reached by A. C. Seward, likewise an eminent authority, who states the case as follows: "The evidence of paleobotany certainly favors the inclusion of the Wealden rocks in the Jurassic series."\*

*Age of the Laramie.*

The problem before us to-day has a strong family resemblance to another with which geologists were face to face twenty years ago; namely, the geological age of the great lignite series of the West. Then as now, the plants and the animal remains seemed to tell a different story, and I was thus led to investigate the question with considerable care. It may perhaps aid in solving the present problem if I repeat what I then said so far as it relates to the value of different kinds of fossils as evidence of geological age. In an address before the American Association for the Advancement of Science, in 1877,† I stated the case as follows:

"The boundary line between the Cretaceous and Tertiary in the region of the Rocky Mountains has been much in dispute during the last few years, mainly in consequence of the uncertain geological bearings of the fossil plants found near this horizon. The accompanying invertebrate fossils have thrown little light on the question, which is essentially whether the great Lignite series of the West is uppermost Cretaceous or lowest Eocene. The evidence of the numerous vertebrate remains is, in my judgment, decisive, and in favor of the former view.

*Relative Importance of Fossils.*

"This brings up an important point in paleontology, one to which my attention was drawn several years since; namely, the comparative value of different groups of fossils in marking geological time. In examining the subject with some care, I found that, for this purpose, plants, as their nature indicates, are most unsatisfactory witnesses; that invertebrate animals are much better; and that vertebrates afford the most reliable evidence of climatic and other geological changes. The subdivisions of the latter group, moreover, and in fact all forms of animal life, are of value in this respect, mainly according to the perfection of their organization or zoological rank. Fishes, for example, are but slightly affected by changes that would destroy reptiles or birds, and the higher mammals succumb under influences that the lower forms pass through in safety. The more special applications of this general law, and its value in geology, will readily suggest themselves."

\* Catalogue British Museum, Wealden Flora, p. 290, 1895.

† This Journal, vol. xiv, p. 338-378, November, 1877.



In the statement I have quoted, I had no intention of reflecting in the slightest degree on the work of the conscientious paleobotanists who had endeavored to solve the problem with the best means at their command. I merely meant to suggest that the means then at their command were not adequate to the solution.

It so happened that the most renowned of European botanists, Sir Joseph Hooker, was then in this country, and to him I personally submitted the question as to the value of fossil plants as witnesses in determining the geological age of formations. The answer he made fully confirmed the conclusions I had stated in my address. Quoting from that, in his annual address as president of the Royal Society, he added his own views on the same question.\* His words of caution should be borne in mind by all who use fossil plants in determining questions of geological age, and they are especially applicable to the problem now before us,—the age of the Potomac formation.

The scientific investigation of fossil plants is an important branch of botany, however fragmentary the specimens may be. To attempt to make out the age of formations by the use of such material is too often labor lost and must necessarily be so. As a faithful pupil of Goeppert, one of the fathers of fossil botany, I may perhaps be allowed to say this, especially as it was from his instruction that I first learned to doubt the value of fossil plants as indices of the past history of the world. Such specimens may indeed aid in marking the continuity of a particular stratum or horizon, but without the reinforcement of higher forms of life can do little to determine the age.

The paleobotanists have certainly failed repeatedly in the past, in attempting to define geological horizons by fossil plants alone. Although they have this record as a guide, some of them are still using the same methods, the same material, with the same confidence, that formerly misled their predecessors. In view of this, and of the great importance of the present question, is it too much to ask them to reconsider their verdict as to the age of the Potomac formation?

Were the fossil plants of the Potomac that have been pronounced Cretaceous unknown, the Jurassic age of this extensive series would have been accepted as a matter of course long ago. The strata themselves lie exactly in the position the Jurassic should occupy. They agree in physical characters more closely with the shallow fresh-water shales and sandstones of the Trias below, than with the deep-sea Cretaceous beds above. Still more important, the animal remains taken together, invertebrates and vertebrates, indicate one fauna, the Jurassic. Under these circumstances, the plants alone cannot finally decide the age.

\* Proceedings Royal Society of London, vol. xxvi, pp. 441, 443, 1877.

*Position of Jurassic Strata.*

In the geological section, figure 1, on page 434, the relative position of the Jurassic deposits of the West is designated, and this will hold good for all the strata of that age in known localities on both flanks of the Rocky Mountains. In the East, the position of the deposits here regarded as Jurassic is equally definite, and corresponds strictly to that of the western horizon in its most essential features. A reference to the section in figure 2, below, will make this clear. This typical section is based on one by G. H. Cook, in the *Geology of New Jersey*,\* and represents the successive Mesozoic and more recent formations, from New Brunswick, New Jersey, on a line southeast, through Lower Squankum to the Atlantic. The relative proportions and inclination of the various divisions cannot, of course, be given accurately in so small a figure. The distance represented by this section is about forty miles.

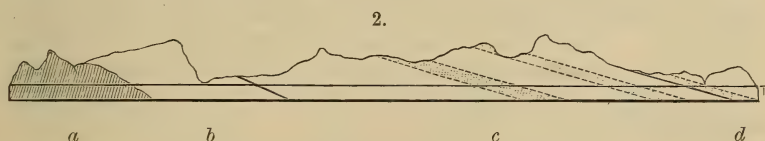


FIGURE 2.—Geological Section in New Jersey.

*a*, Triassic; *b*, Jurassic; *c*, Cretaceous; *d*, Tertiary; *T*, tide level.

In this section, the red Triassic shales and sandstones are shown on the left, highly inclined. Resting on their eroded surface are the well-known variegated plastic clays, also of fresh-water origin. These strata are nearly horizontal, having a slight inclination toward the ocean. The top of these peculiar clay beds is not clearly defined, but is marked by a change from lacustrine to marine conditions, which clearly indicate deposition in water of increasing depth, and finally deep-sea glauconite strata. These greensand deposits continued with some interruptions throughout the remaining Cretaceous time, and even into the early Tertiary, the third, or upper, marl bed being Eocene. Over these are strata of Miocene age, the *Ammodon* beds, and still more modern deposits form the shore of the Atlantic.

*Atlantic Barriers.*

The change from the fresh-water plastic clays of New Jersey to the marine beds containing greensand over them proves not only the breaking down of the eastern barrier which protected the former strata from the Atlantic, but a great subsidence also, since glauconite, as a rule, is only deposited in the deep, still waters of the ocean.

\* *Geological Map, Cretaceous Section 3, 1868.*

The Miocene greensand surmounting the Gay Head clay cliffs on Martha's Vineyard also means the same thing, and a still greater lapse of time, as the whole Cretaceous and Eocene strata are here apparently absent. The present height of these Miocene strata indicates indirectly the minimum of elevation, the depth of the sea in which they were deposited being at present one of the unknown elements. It has been suggested by some geologists that the eastern barrier was composed of granitic rocks, and thus furnished the materials for the New Jersey and other clays.\* Many known facts support this view.

The western, or inner, barrier of this great fresh-water border lake is still well marked. In the New England region, the present rock-bound coast line indicates its approximate position, and retains in its bays and inlets remnants of the deposits then laid down. Away from the coast, I know of only a single locality that seems to have preserved these beds, and that is near Brandon, Vermont. This basin I explored long ago, and if my memory serves me rightly, I saw there the typical clays, lignites, and iron ores, that mark the horizon now under consideration. South of New England, the inner barrier is equally well defined by the Triassic and older rocks to the Potomac River, but beyond that point I have not carefully examined it.

#### *Physical Characters of the Jurassic.*

The strong resemblance in their physical characters between the fresh-water deposits here regarded as Jurassic and those long known to be such in the Rocky Mountain region is largely dependent on the materials of which they are formed, and the conditions under which they were deposited. The close correspondence in this respect between the beds of the two regions should have some value in estimating their age.

The most striking feature in these deposits is the variety of colors in the plastic clays. Brilliant red, green, and yellow tints are especially prominent, yet the white and black shades are equally noticeable. While these colors are often seen in great masses, marking definite strata in fresh exposures, they blend one with another from the effects of weathering, where the original colors wash over each other. In the Rocky Mountain region, the brilliant hues of the Jurassic strata may be seen for miles on the face of the high bluffs. This is especially remarkable in the cliffs at Como, Wyoming, a representation of which is before you. Still more brilliant effects may be seen in the canyons on the west side of the Green River, in Eastern Utah.

East of the Rocky Mountains, the same color scheme is well illustrated around the Black Hills, in South Dakota. Again in the foot-hills west of Denver, near Morrison, Colorado, a

\* Geology of New Jersey, Report on Clays, p. 30, 1878.



similar exhibition is to be seen, as represented in the second drawing. This is repeated on a much larger scale further south, near Cañon City, Colorado, as likewise shown in still another sketch, but none of these colored drawings does justice to the natural scenery.

On the Atlantic coast, the same combination of colors, although less brilliant, may be seen in the Potomac outcrops in Maryland, now proved by vertebrate fossils to be likewise Jurassic. Further north, the reds predominate in this horizon across Delaware and Pennsylvania, but in the plastic clays of New Jersey, the strong distinct colors, usually in horizontal bands, are dominant. On Staten Island and at various outcrops along the northern shore of Long Island, as well as on Block Island, the same horizon is distinctly marked by variegated patches, while still further east, at Gay Head, on Martha's Vineyard, the most startling color display of the whole Atlantic coast forms a flaming beacon that mariners and geologists alike have for a century held in high esteem. I know of no other horizon of equal extent so readily distinguished from all others by its physical features.

#### *Early Investigations.*

In the early days of American geology, the pioneers here, as in other branches of science, attempted to refer everything to European standards. In this way, strata of various ages, as we now know, were called by European names, and were supposed to represent equivalents. In this general way, the terms Lias, Oolite, etc., were applied to strata on the Atlantic coast. It was soon found, however, by the actual workers in the field, that our geological sequence had only a general correspondence with that of Europe or of other parts of the world, yet some geologists still endeavor to harmonize the time tables, but with only moderate success. It is, however, now becoming known, that this continent had its own law of development, and that its fauna and flora must be studied by themselves to disclose their full significance. The time ratios of America certainly do not coincide with those of Europe. The long periods of Mesozoic time represented in Europe by great deposition of many series of strata were marked here by other means as well. The rich fauna and flora that then lived here do not have their exact counterparts elsewhere.

The apparent absence on the Atlantic coast of the Jurassic as known in Europe naturally led the early geologists to seek its equivalent strata. The first supposed identification seems to have been recorded by W. B. Rogers, who called the eastern Virginia coal beds Oolitic.\* These beds are now regarded as Triassic.

\* Transactions Association American Geologists and Naturalists, vol. i, p. 300, 1843.

This eminent geologist also referred to the Jurassic certain silicious, argillaceous, and pebbly beds in Virginia and further north, as possibly "a passage-group analogous to the Wealden of British geology."\* P. T. Tyson in 1860 referred the Maryland clays to the Cretaceous, and later to the Jurassic.†

Long before this, in 1835, H. D. Rogers, in his sketch of the geology of North America, clearly recognized what is here regarded as Jurassic as pertaining to one great formation. He described this as extending along the tide water plain of the Atlantic, from the Carolinas through Virginia, Maryland, Delaware, Pennsylvania, and New Jersey, and also as continuing on through Long Island to Martha's Vineyard and Nantucket. He gave it the name of "Ancient Alluvium," but included in it the plastic clay formation and part of the Gay Head deposits, the latter of which he considered Cretaceous.‡

The next noteworthy description of the Jurassic as here defined was given by J. C. Booth in his report on the Geological Survey of Delaware, 1841. He described the variegated plastic clays of that state, and gave to them the name of "Red Clay Formation," which he regarded as belonging to the Upper Secondary. The more recent publications on this Atlantic Coast formation are well known, and need not be cited here.

Among the early explorers who contributed to our knowledge of the Jurassic of the Rocky Mountains and Pacific coast region were J. Marcou, in New Mexico, 1853; C. King, in California, 1863; and, in the same state, W. Gabb, 1864, and F. B. Meek, 1865.

The earliest discovery of the Jurassic in the Arctic region of this country was by Sir E. Belcher, in 1852, who found remains of *Ichthyosaurus* on Exmouth Island. The latest information in regard to the Jurassic comes also from the Arctic region, where Nansen has found this formation containing many fossils, near Franz Joseph Land.

#### *Jura-Trias.*

The term Jura-Trias now in use is in reality a confession of ignorance, excusable, perhaps, a quarter of a century ago, but unpardonable now in those whose duty it is to map or define the formations of this country. Yet this term is still sometimes used for so clean-cut a Triassic horizon as the Connecticut River sandstone. It is true that in early days of New England geology, this formation was in part referred to the Jurassic, but at the present time no one at all familiar with the evidence of the abundant vertebrate life found in it could make such a mistake. This is equally true of the southern extension of the same formation along the Atlantic coast, where it is everywhere quite distinct from the Jurassic. In the West, the dividing line is less marked in some regions, but I believe that even there careful explorations alone are required to separate these two allied formations.

\* Proceedings Boston Society, vol. xviii, pp. 104, 105, 1875.

† 1st Report State Chemist, Maryland, p. 41, 1860; 2d Report, p. 54, 1862.

‡ Report British Association, Edinburgh Meeting, pp. 1-66, 1835.

*Vertebrate Fauna of the Jurassic.*

The Jurassic age of the Atlantosaurus beds of the West has now been demonstrated beyond question by the presence of a rich fauna of mammals, birds, reptiles, and fishes. Among these, the *Sauropoda* were dominant, and the other Dinosaurs well represented.

In the Potomac beds of Maryland, the same Jurassic vertebrate fauna is present, as shown by the remains of five different orders of reptiles already discovered in them. Among the Dinosaurs are the *Sauropoda*, the *Theropoda*, and the *Predentata*, the first group represented by several genera and a great number of individuals. One of these genera is *Pleurocoelus*, which has also been found in the Jurassic of the West. Besides the Dinosaurs, characteristic remains of *Crocodylia* and *Testudinata* are not uncommon, and various Fishes have been found. The remains of these six groups already known are amply sufficient to determine the age of the formation, and still more important discoveries doubtless await careful exploration.

The discovery of vertebrate fossils further east is merely a question of systematic work. That they are there, all experience in this horizon clearly indicates. In 1870, I passed over miles of similar strata on the eastern flanks of the Uinta Mountains, with every man of my expedition on the lookout for fossils, prompted both by zeal for science and a special reward for the first specimen, but also on the alert for the hostile Ute Indians around us, yet not a fossil was seen. Ascending a few hundred feet, I found the sides of a narrow canyon full of fossils, vertebrate and invertebrate, all of Jurassic forms. The stratum once established, the supposed barren clays soon furnished rich localities.

The similar Potomac clays were formerly pronounced quite destitute of animal remains by geologists of eminence, but hard work disclosed their treasures. The coast east of the Hudson has an abundance of the same strata, and offers still greater rewards to explorers. The Gay Head Indians are not hostile, but will be found active assistants in the good work, while holding fast to the traditions of their ancestors as to the volcanic origin of their narrow sea-scourged home.

*Long Island Sound.*

It is evident that we know the remnants only of the great formation we are now discussing, for the larger part of it has long since been swept away, and much of the remainder is covered up or obscured by later deposits. The origin of this formation is a great question in itself, while its gradual destruction offers still larger problems to the geologist. One of these only I have time now to touch upon, and that has special interest for me, as day by day from my study window I look across the Sound to Long Island.



The origin of Long Island Sound was doubtless largely dependent upon the soft Jurassic clays that once filled its bed. The barrier on the north was the rock-bound New England coast essentially as it is to-day. The outer barrier, now removed or beneath the ocean, was perhaps of less durable material, and, as the coast subsided, gradually succumbed to the assaults of Atlantic waves. The great terminal moraine at the close of the glacial period proved a second barrier, and the waters from the melting ice and the larger rivers sought an outlet to the sea, both east and west, and thus a channel was formed in the soft clays and sands that the strong ocean currents gradually enlarged to its present size.

### *Conclusion.*

The problem now before us is the presence or absence, on the Atlantic coast, of strata of Jurassic age. The exact position where such deposits should be found, if present, is well known to all geologists familiar with our eastern border. The fresh-water Triassic beds below this position and the extensive marine Cretaceous above have long ago been carefully studied, and their exact limits defined.

For many hundred miles, along the line where the Jurassic should occur, there is a well-marked series of fresh-water clays and sands quite distinct from anything else on the coast, and the question is,—are these beds of Jurassic or Cretaceous age? The prevailing opinion hitherto has been strongly in favor of the latter, although this view separated two allied fresh-water formations, and still left out the great Jura, so well represented in other parts of the world, and especially in our own Rocky Mountain region.

How difficult it is to lay aside preconceived opinions, everyone knows. The long supposed absence of the Jurassic on the Atlantic coast seems to have blinded those who had the formation under their feet. The evidence to-day in favor of its presence, if not conclusive at every point, is vastly greater than the opposing testimony. Moreover, its acceptance explains at once a mystery of long standing,—why the records of Jurassic time were not preserved here in their true place.

To call this peculiar Atlantic formation Cretaceous in its various eastern outcrops, when the western expansion of the same characteristic deposits has been proved Jurassic, is certainly not scientific. To do this in the light of present testimony, including the animal remains, vertebrate and invertebrate, the unique structure and materials of the strata themselves, and especially their definite position where the Jura should be, is to violate the laws of evidence.

No geologist familiar with the facts will deny that the variegated Potomac clays in Maryland are continuous with those in Delaware, Pennsylvania, and New Jersey, and that the similar basal clays on Long Island, and the other islands to the eastward as far as Nantucket, are part and parcel of the same series. There is now positive proof that the southern end of this series is Jurassic, and it is certainly a fair conclusion that the remainder is of the same age. The burden of proof will rest upon those who hold to the contrary.

To place the strata in question in the Jurassic section of the Atlantic coast at once removes many difficulties that have hitherto perplexed students of the Mesozoic of this region. It completes the series, and shows in part, at least, what was done in deposition during that long interval between the end of Triassic and the beginning of Cretaceous time, when the great barrier was broken down, which, from the Devonian to the Cretaceous, shut out the waters of the Atlantic.

I must leave it to others with leisure at their command to work out the details of this well-marked series, and its relation to those above and below. I have no time to devote to the surface geology of this belt or to the earlier deposits of Tertiary time. Just now, the Mesozoic interests me most of all, especially its middle section, the Jurassic, as I believe great injustice has been done, since this has been denied its rightful place, and a name not its own stamped upon it.

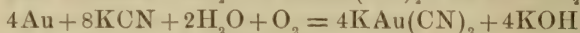
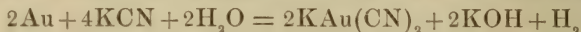
In a later communication, I hope to discuss this question further, and especially the Jurassic beds south of the Potomac River.

Yale University, New Haven, Conn., November 16, 1896.

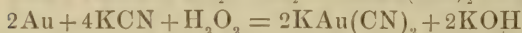
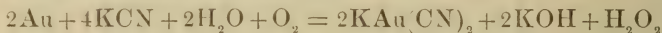
## SCIENTIFIC INTELLIGENCE.

## I. CHEMISTRY AND PHYSICS.

1. *The chemistry of the Cyanide Process.*—Two views have been expressed concerning the chemical reaction which takes place in this very important, recent process for extracting gold from its ores. These are represented by the following equations:



The second equation represents the view which is now generally accepted, and BODLAENDER has recently shown conclusively that no hydrogen is evolved when gold is placed in contact with potassium cyanide solution. He placed finely divided gold and the cyanide solution in an exhausted retort, and after a contact of fourteen days no hydrogen could be detected. He showed, moreover, that the presence of oxygen was necessary for the dissolution of the gold, but he has found that the commonly accepted equation, the second one given above, does not fully represent the reaction, but that hydrogen peroxide is at first produced and that the reaction takes place in two stages, viz.,



The author proved conclusively that hydrogen peroxide is produced in the reaction, and that its formation is more abundant the more rapidly the solution of the gold takes place. When the hydrogen peroxide was removed as fast as it was formed by having calcium hydroxide present in the solution (thus producing a precipitate of calcium peroxide), the author was able to obtain about two-thirds of the theoretical hydrogen peroxide by quantitative determination.—*Zeitschr. für angew. Chem.*, 1896, 583.

H. L. W.

2. *Beryllium not isomorphous with the metals of the magnesium group.*—The true place of beryllium in its relation to other elements has been a matter of much discussion. It is at present generally admitted that it is a bivalent element, and the isomorphism of its salts with those of the metals of the magnesium group is assumed by the authors of certain text books, although such isomorphism does not appear to have been distinctly proven. RETGERS has now made a careful study of the crystallization of mixtures of beryllium sulphate and the sulphates of copper, nickel, iron and manganese, and has discussed the results of Klatzo, who used the sulphates of magnesium and zinc in the same way with beryllium sulphate, as well as the results of Marignac and of Atterberg in connection with beryllium and magnesium salts. He finds that there is no evidence of the isomorphism of beryllium with any of these metals. He believes also that the apparent



isomorphism of phenacite and willemite, as well as that of beryllium oxide and zinc oxide, and of the two metals beryllium and magnesium, may be accidental.—*Zeitschr. für physikal Chem.*, xx, 481.

H. L. W.

3. *The non-existence of two Orthophthalic Acids*; by H. L. WHEELER, from the advance sheets of an article to be published in the *American Chemical Journal*.—In the June number of this *Journal* of the present year, vol. i, p. 485, an article by Mr. W. T. H. Howe upon the existence of two orthophthalic acids was briefly reviewed. Dr. Wheeler now shows conclusively that no new acid can be prepared by the methods given by Howe, and it is evident that the facts upon which Howe's article was based were false, and the theoretical conclusions, interesting and important as they seemed, were without foundation.

H. L. W.

4. *Humphry Davy, Poet and Philosopher*; by T. E. THORPE, 8vo, pp. 240. New York, 1896 (Macmillan & Co., price \$1.25).—This book, appearing in the "Century Science Series," has as its subject one of the most notable and interesting pioneers of chemistry. Sir Humphry Davy was perhaps the greatest of England's popular lecturers upon scientific subjects, and among his great discoveries we owe to him the first knowledge of the effects of breathing nitrous oxide, the discovery of the alkali and alkali-earth metals by the use of electrolysis, the recognition of chlorine as an elementary body, and the well-known safety lamp. Professor Thorpe has handled his subject in his usual charming style, and has made the book a fascinating one, not only to the chemist, but also to the general reader. Much material, hitherto unpublished, has been introduced. The author has not failed to give a good impression of Davy's genius, but he has also allowed us to understand his frailties and peculiarities.

H. L. W.

5. *Chemistry in Daily Life*; by LASSAR-COHN. Translated by M. M. PATISON MUIR, 8vo, pp. 324. Philadelphia, 1896 (J. B. Lippincott Company, price \$1.75).—This series of twelve popular lectures is very well adapted to give the general reader some idea of the simplest and most important principles of chemistry, as well as a good insight into the important applications of chemistry at the present day. The wide range of subjects touched upon may be seen from the following list of a few of them: Breathing, air, ozone, maintenance of the warmth of the body, combustion, nature of flame, fats, petroleum, the elements, chemical formulæ, the atom and the molecule, distillation, the manufacture of coal-gas and by-products, incandescent gas-lights, food of plants, bases acids, and salts, food of men and animals, common salt, importance of cooking, fermentation, alcoholic beverages, vinegar, wood spirit, explosives, wool, cotton, silk, shoddy, tanning, parchment, bleaching, drying, oil painting, varnishes, inks, paper, potash, Leblanc's process, nitric acid, bleaching-powder, ammonia soda process, soap, glass, clay, pottery, photography, the X-rays, noble and base metals, ores, bimetalism, iron and steel, regenerator furnaces, zinc, electro deposition of metals, alloys, alkaloids, antiseptics.

H. L. W.

6. *Practical Methods of Organic Chemistry*; by GATTERMANN, translated by W. B. SHOBER, 8vo, pp. 330. New York, 1896 (The Macmillan Company, price \$1.60).—This book, designed for students doing laboratory work in organic chemistry, has met with a cordial reception in Germany, where this branch of instruction has attained a high degree of development. It is therefore gratifying to notice the appearance of a satisfactory English translation of this valuable book. It will be an important aid to the teaching of the subject to English-speaking students and will doubtless find an extensive use in our universities. H. L. W.

7. *The Chemical Analysis of Iron*; by A. A. BLAIR, third edition, 8vo, pp. 322. Philadelphia, 1896 (J. B. Lippincott Company).—This work is the recognized authority upon the analysis of iron, steel, iron ore, slags, fuels, etc., and it is indispensable in laboratories where such analysis is practiced or taught. In the new edition many minor changes and several important additions have been made, so that it may be considered, as it purports to be, "a complete account of all the best known methods." H. L. W.

8. *Physikalisch-chemische Propädeutik*; by H. GRIESBACH, 8vo, erste Hälfte and zweite Hälfte, 1 Lieferung, pp. 592; the last "Lieferung" is to appear soon. Leipsic, 1895-6 (Wilhelm Engelmann).—This text-book is designed to give a general view of physical and chemical science, especially from a medical standpoint. The book covers a very wide range of subjects, and these are treated in such a manner that the reader has no need of special scientific knowledge. There is much historical information and numerous biographical notes concerning scientific discoverers and investigators are given. There are also copious bibliographical references. The book is accurate and modern, and it furnishes a valuable source of information for many classes of readers. H. L. W.

9. *On methods of determining the dryness of saturated steam and the condition of steam gas*;\* by Prof. OSBORNE REYNOLDS.—In certain recent attempts to ascertain the proportion of steam and water in the fluid which enters a steam engine, by means of what is called the wire-drawing calorimeters, the published results show that there remains from 0 to 5 per cent by weight of water in the steam, after it has been drained by gravitation, in the same manner as the steam on which Regnault's experiments were made. This has necessarily excited great interest in steam engineering, and is naturally welcome, as it apparently brings the performance of the engines by so much nearer perfection. Although the result of these recent experiments appear to show the condition of dry saturated steam to be other than that on which Regnault's experiments were made, and from which the present steam tables have been calculated, still these tables have been used in deducing the percentage of water latent in the steam.

\* Abstract received from the author of a paper read before the Manchester Literary and Philosophical Society, Nov. 3d, 1896.

Whereas, if the latent water exists, it must have existed in the steam used by Regnault, and the steam tables must also be subjected to identical corrections; and, consequently, the percentage of theoretical performance of steam engines would be unchanged.

It is then pointed out, that, in the reduction of such of these results as have been published, use has been made of Regnault's determination of the specific heat at constant pressure of steam gas (0.48) in a manner which is not consistent with the theory of thermodynamics. Thus, in Rankine's notation,  $S_1$  is the weight of steam per lb. of fluid, and  $H_1$  the total heat per lb. from  $0^\circ \text{C.}$  to  $T_1^\circ$ ,  $h_1$  the heat required to raise water per lb., and  $H_2$ ,  $h_2$ ,  $T_2$ , the corresponding values for saturated steam at the pressure after wire-drawing, and  $T_s^\circ$  the observed temperature after wire-drawing.

The notation assumed for the equation of heat, neglecting incidental losses, is

$$S_1 (H_1 - h_1) + h_1 = H_2 + 0.48 (T_s^\circ - T_2^\circ) \dots 1$$

Whereas, it has been proved by Rankine that the thermodynamic expression for the total heat in superheated steam at  $T_s^\circ \text{C.}$ , provided it has reached the condition of steam gas, to which the 0.48 only applies, is

$$C_1 + 0.48 (T_s^\circ - T_0^\circ)$$

$C_1$ , being a constant, depends only on the temperature of the water ( $T_0^\circ$ ) from which the steam is produced, the value of which from  $0^\circ \text{C.}$  is 606.7, approximately, as deduced by Rankine.

Using Regnault's formula for  $H_2$ , the right member of equation (1) becomes

$$606.5 + .305 T_2^\circ + 0.48 (T_s^\circ - T_2^\circ)$$

while the value by the thermodynamic formula is

$$606.7 + 0.48 T_s^\circ$$

which gives as the excess of heat over that assumed

$$0.2 + 0.175 T_2^\circ$$

This excess, if  $T_2$  were  $100^\circ \text{C.}$ , is 17.7 thermal units, and if the initial steam pressure were 200 lbs. above the atmosphere, the latent heat being 467.5 thermal units, the percentage of water it would evaporate, at boiling point, is

$$\frac{17.7}{467.5} = 3.8\%$$

which is about as much as needs to be accounted for.

It is also shown that, in order to render Rankine's formula applicable to wire-drawing experiments, it is necessary that the wire-drawing should be continued till the steam is gaseous, whence arises the difficulty of securing that this state has been reached. This, however, may be secured by lowering the pressure gradually after wire-drawing, and so increasing the extent of wire-drawing while observing the temperature ( $T_s^\circ$ ), which, after falling, will gradually become constant as the wire-drawing



increases, and, when constant, will be a definite indication of this gaseous state.

The necessary conditions to ensuring accuracy are then considered, and, in conclusion, it is stated that a research to verify these conclusions has been commenced by Mr. J. H. Grindley, B.Sc., in the Engineering Laboratory of Owens College, Manchester.

10. *Temperature in Geissler tubes.*—Mr. R. W. Wood has carried out a series of measurements in such tubes. The form of tube permitted a bolometer wire to be moved from point to point. The tubes were excited by 600 Planté cells, which gave about 1,250 volts. The electric current was measured by a torsion galvanometer and its strength regulated by a resistance which consisted of a glass tube filled with a solution of iod-cadmium in amyl alcohol. The tubes were filled, in most cases, with nitrogen, although hydrogen tubes were also used. With hydrogen under a pressure of 1.8<sup>mm</sup> and a current of 0.0015 ampere, a rise of temperature of 2.5° was observed. Nitrogen under similar conditions gave a rise of 21.7°. Curves are given of the run of temperature in the stratifications, and in the anode light.—*Ann. der Physik. und Chemie*, No. 10, 1896, pp. 238-251. J. T.

11. *Images in the field of a Crookes tube*; by N. OUMOFF and A. SAMOÏLOFF.—The influence exercised by a Crookes tube on electrified bodies shows that the electric field created in the interior of the tube extends also to the exterior. To study this exterior action the authors replaced the photographic plate by a plate of ebonite. After excitation of the tube the ebonite is quickly withdrawn and the objects placed upon it are thrown off, and the plate is then sprinkled with a mixture of sulphur and minium. The sulphur adheres to the portions which are positively electrified, and the minium to those which are negatively electrified. Thus the color of the spots shows the electric condition of the shadows, and the modifications in the exterior electric field. It was found that the duration of the action of the Crookes tube has an influence on the clearness and intensity of the image. The authors prove that the yellow color of the image corresponds to the parts of the figure directly attacked by the X-rays, the red color to the images of the objects, and the neutral bands to the shadows which surround the images in certain cases. The authors attribute the effects observed to electric fluxes proceeding from the tubes and the objects in its neighborhood, together with a dielectric polarization.—*Phil. Mag.*, October, 1896, pp. 308-314. J. T.

12. *Röntgen rays.*—It has been suspected by various observers that there are different kinds of X-rays. At a late meeting of the Royal Academy of Sciences, Amsterdam, Professor HAGA exhibited two negatives which apparently showed the existence of several kinds of X-rays. At a high degree of rarefaction in the Crookes tubes the penetrating power of the rays through flesh and bone is very different, so that the outlines of the bones are

very distinct; whilst with less rarefaction, these two bodies transmit the rays in about the same degree (Nature, Oct. 29, 1896). It is thought, however, by certain observers that the bones become phosphorescent under certain energy of excitation, and therefore the field of view exhibits less contrasts. It has been discovered that fluorescent screens in order to be of use should not be phosphorescent: for this residual phosphorescence renders the contrast between bones and flesh less evident. A determination of the wave-length of the X-rays has been made by L. Fomm (Ann. der Physik und Chemie, No. 10, 1896, p. 350). He obtained through a slit evidences of interference phenomena similar to those observed in the case of ordinary short waves of light, and by means of a formula given by Dr. V. Lommel for the case of such interference phenomena he obtained the wave length  $\lambda = 0.000014^{\text{mm}}$ . This wave length is at least fifteen times smaller than the shortest hitherto observed wave length of ultra violet light. A. Winkelmann and K. Straubel (Ann. der Physik und Chemie, No. 10, 1896, p. 324) call attention to the remarkable sensitiveness of fluorspar to the X-rays. The portion of a photographic plate beneath a plate of this mineral which is exposed to the X-rays becomes as black as if it were submitted to direct daylight. Unfortunately it is impossible to procure large plates of fluorspar to cover photographic plates. When the mineral is pulverized and sifted on a sensitive plate it does not seem to act as well as when it is in moderate-sized pieces. The use, however, of large pieces mottles the sensitive plates and destroys the definition of objects photographed on it.

J. T.

13. *The Principles of the Transformer*; by FREDERICK BEDELL, PH.D. xii + 404 pp. New York, 1896 (The Macmillan Company).—This book is, in a measure, a continuation of Bedell and Crehore's "Alternate Currents," and is similar to it in general aim and methods of treatment. The same clearness of reasoning and lucidity of style which have justly rendered the previous work popular among students are apparent in this volume also. Occasionally, however, the desire for clearness in demonstration seems to have led the author almost to the verge of prolixity; for example, it is difficult to see the utility of such minute detail in the treatment of the general equations of the transformer in Chapter XI; it can hardly make the subject intelligible to those readers who have no acquaintance with determinants or elementary differential equations, and is, on the other hand, scarcely necessary for those whose mathematical studies have included these subjects.

A dual method of treatment is adopted, many of the problems being solved by analytical treatment, and also graphically by means of the polar diagram. In the first twelve chapters the theory of the transformer with constant coefficients of induction is gradually developed with greater and greater generality; then follow several special problems, and chapters on design and construction, experimental diagrams and transformer testing. The

final chapter is upon the effects of hysteresis and Foucault currents; it is to be regretted that this portion of the subject has not been treated at greater length.

One admirable feature of the book is the adoption of a consistent notation throughout, and the collection of the symbols used, with their definitions, in a separate chapter. In this connection a sentence or two may be quoted from the author's preface, which will probably command the approbation of most readers who object to the abuse of their mother-tongue even in technical periodicals. "Over-abbreviation and the introduction of heterogeneous prefixes and suffixes *ad libitum* the author views as a mania of the day, which proves a source of confusion rather than an aid to the reader. . . . The introduction of new terms and units has been carefully avoided."

Altogether the work deserves commendation and can scarcely fail to be of great use to students of electricity.

14. *The Elements of Physics, Vol. II. Electricity and Magnetism*; by EDWARD L. NICHOLS and WILLIAM S. FRANKLIN. pp. ix + 261. New York (The Macmillan Co.).—It has evidently been the intention of the authors, in this book, to reduce the important laws governing electrical quantities to mathematical expressions, rather than to prepare a comprehensive text-book of electricity. The volume may be not unfairly described as a rather full note-book on the mathematical theory of electricity and magnetism. It opens with an introductory chapter on the treatment of distributed quantities. The ideas and analytical methods presented here are much more difficult than those used elsewhere throughout the book.

The order of treatment is unusual. The fundamental concept is a magnet which is thus defined (Art 327, a.): "A bar of steel which has been treated in a manner to be described later is called a magnet." From this definition are developed the usual expressions for the magnetic quantities, but how the bar of steel was treated is nowhere explicitly stated. The electric current is then defined by the equation  $F = Ilf$ , where  $F$  is the sidewise push on a wire of length  $l$  in a field of strength  $f$ , and later an electric charge, as the time integral of the current. After a discussion of electrolysis, batteries and resistance, charge is again introduced in the chapter on Electrostatics and defined by Coulomb's law, as if it were an independent quantity. Succeeding chapters discuss phenomena of discharge, magnetism in iron, induced electromotive force, thermo-electric currents, practical applications, and mechanical conceptions of the electric and magnetic fields.

The diagrams are numerous, simple and clear. A little more care should have been exercised in the order of presentation. Terms and instruments are often introduced before they have been defined, or described; e. g. current p. 31e, battery p. 66, induction coil p. 168. Equations 213 and 238 contain errors for which the proof-reader is to blame. There are numerous examples of careless writing. In Art 359 a galvanometer is said



to "depend on equation 204 for its action." In Art 517 we read of the "flow of magnetic flux." In Art. 582, equation 2 is ascribed to Cavendish but in Art. 330 to Coulomb. The numerical value of the velocity of light is virtually given in four different ways, 300.2, 298, 300, and 299 million meters per second.

15. *Alternating Currents and Alternating Current Machinery*; by DUGALD C. JACKSON, C.E., and JOHN PRICE JACKSON, M.E. pp. xviii and 729. New York (The Macmillan Co.).—This book forms the second volume of Jackson's Text-Book on Electro-Magnetism and the Construction of Dynamos. It is a work intended for the use of students of electrical engineering. In so far as we may judge, without having put the book to actual test in the designing room, the authors have well fulfilled their aim to develop a clear exposition of the principles governing the design of electro-magnetic machinery, and present the elements of present engineering practice. The style is concise but never scrappy. Whenever theory can serve as a guide in the construction of a machine and mathematics is necessary, it is introduced, the necessary formulas being derived from the beginning. Difficulties are not slurred over nor, on the other hand, does the book have the peculiar character of a mathematical treatise. For the more purely empirical parts of the subject numerous tables are introduced. A large number of diagrams and line drawings serve to illustrate the text, but mere pictures of commercial machinery have been excluded. Methods of measuring the various magnetic quantities, and of testing alternators and transformers, are described at length.

On casual reading there appear very few things indeed that suggest adverse criticism. The classification of armatures (p. 15) seems artificial and of little value. The sentence (p. 78) "All insulated conductors have the property of being able to hold electricity in its static form," might lead the reader to infer that electricity existed in different forms, one of which is known as the static. On the whole the book may be said to be an excellent one for the sphere for which it was written.

## II. GEOLOGY AND MINERALOGY.

1. *On some Palæozoic fossils from Baffinland*; by E. M. KINDLE. (Communicated.)—During the past summer the writer obtained, while with the Cornell University Arctic Expedition, two small collections of fossils from Baffinland. The first of these was collected from the mainland north of Hudson Strait, about lat.  $62^{\circ} 45'$  and long.  $70^{\circ}$  W., and from Big Island. The other set of specimens was collected by Mr. Peck, a missionary, who obtained them from the shores of Lake Kennedy, which lies northwest of the head of Cumberland Sound. All of the specimens from Big Island and Hudson Strait were picked up from the drift. These are embedded in hard, fine-grained, light-gray limestone, which occurs in small fragments very sparingly dis-

tributed among the gneiss boulders which everywhere encumber the surface. Sections of *Crinoid stems* occur abundantly in these limestone fragments. Associated with them are several specimens of *Zaphrentis*. These are not sufficiently well preserved to admit of specific identification.

Aside, however, from the little interest which the few poorly-preserved specimens from Big Island may have as fossils, they are worthy of mention because of their relation to the glacial history of the island. Big Island has a north and south diameter of about fifteen miles, and is separated from the mainland by White Strait, which is from three to ten miles wide. The Island, which is now free from ice, presents everywhere evidence of former glaciation. The observations of Mr. T. L. Watson and Mr. J. A. Bonesteel, who spent three days exploring the island, indicate that no limestone beds occur on it. It would seem, therefore, that the limestone erratics picked up on the Island, as well as those from the coast of the mainland, were derived from the interior of Baffinland, probably from the region above Frobisher Bay, where Capt. Hall found a limestone formation. From the mainland they were probably transported by an ice cap, which extended across White Strait and enveloped Big Island, to the position where they were found.

From the Lake Kennedy specimens, all of which appear to be from the same limestone, I have recognized the following species:

*Zaphrentis*, sp.?

*Halysites catenulatus* Linn.

*Machurea magna* Hall?

*Endoceras proteiforme* Hall.

*Zaphrentis* is a wide-ranging genus and is, therefore, of no value for purposes of correlation. *Machurea magna* and *Endoceras proteiforme* are both Ordovician species occurring in the Trenton. *Halysites catenulatus*, however, is generally regarded as a characteristic Niagara form, although it has been reported from the Ordovician.\* This association of Silurian and Ordovician species may have resulted from the mixing of specimens originally from distinct horizons, but, on the other hand it may express an association in a common fauna of species, which in other regions were restricted to different geological horizons.

2. *United States Geological Survey, 16th Annual Report, Part I, Director's report and papers of a theoretic nature*: C. D. WALCOTT, Director, pp. i-xxii, 1-910, plates i-cxvii, figs. 1-168. Washington, 1896.—This latest published of the four large volumes of the sixteenth annual report contains several papers of special importance:

"The Dinosaurs of North America," by O. C. Marsh, will receive special notice elsewhere. "Principles of North American pre-Cambrian geology," by Chas. R. Van Hise, with an appendix by Leander M. Hoskins, has been presented in an abstract by the

\* Jour. Cin. Soc. Nat. Hist., vol. xviii, Nos. 3 and 4, p. 165.

authors on pages 205-213 of this volume. Mr. Dale's paper on "Structural details in the Green Mountain region," is described on page 395. Mr. Harry Fielding Reid contributes an illustrated report on "Glacier Bay and its glaciers," with numerous important statistics regarding the general features and the changes now going on in this Alaskan glacier region.

In the paper "Some analogies on the lower Cretaceous of Europe and America," the author, Lester F. Ward, in the first part makes comparison of the Potomac formation with that of the Wealden of England, and finds reason for considering them closely related as indicated by their respective floras; secondly, the scaly clays of Italy, their cycads and the age of the beds are discussed; and thirdly, the Jurassic and Cretaceous floras of Portugal are compared with the corresponding floras of America.

3. *Biological Lectures, Wood's Holl, summer season of 1895.* pp. 1-188, 1896—The latest number of this series contains several papers of general interest.

Two of the lectures were on the head segments of vertebrates. WILLIAM A. LACY in "The primary segmentation of the vertebrate head," reaches the conclusion that there are normally fourteen neural segments. He says: "The human brain is not a homogenous mass of tissues, but a *complex* compound of an aggregation of about fourteen brains all united into a working whole." Professor G. S. KINGSLEY, in the following lecture, on "The segmentation of the head," after noting the varying interpretations of previous investigators, accepts the observations of Mr. Lacy as to matters of fact, but hesitates to adopt his interpretation, remarking that "while we can say that there are certainly more than the three or four segments of Oken and his followers, we cannot say exactly what the number is. Before the answer is placed beyond a doubt, a number of other questions must be solved, not the least of which is the broader problem of the origin of metamerism and the relation of this condition in the vertebrates to that in the lower forms." Significant, as bearing upon this latter suggestion, is the recent address of Dr. Gaskell, before the physiological section of the British Association this summer, on the "origin of vertebrates," in which he traces it to the merostomata, chiefly by means of the neural segmentation.

Another investigation presented in the Wood's Holl series is on "the transformation of Sporophyllary to vegetative organs," by Professor GEORGE F. ATKINSON. The author observes the remarkable facility with which the normally differentiated sterile and fertile leaves of the *Onoclea sensibilis* replace one another. He draws the conclusion that the sporophylls are primary organs, here agreeing with Bower, and are transformed into vegetative leaves. Aside from this special result of the investigation, the remarkable variability in the degree of differentiation of the two kinds of leaves is a warning, especially to paleobotanists, against drawing too hasty generalization from the separate fragments of fossil ferns met with in the rocks.



Professor W. B. SCOTT, in the lecture on "Paleontology as a Morphological Discipline," though presenting no original investigations, appropriately calls the attention of biologists to the importance of paleontological studies toward the solution of the perplexing problems of biology. He mentions "one or two principles which stand out with especial clearness as the deductions drawn from paleontological study of phylogenetic series. These are (a) "Evolution is ordinarily a continuous process of change by means of small gradations," although "this does not imply that the rate of change was always uniform,—it probably was not,—or that a sudden alteration of conditions may not bring about discontinuity, or *per saltum* development."

(b) "Development is, in most instances, direct and unswerving."

(c) "Parallelism and convergence of development are much more general and important modes of evolution than is commonly supposed. By parallelism is meant independent acquisition of similar structure in forms which are themselves nearly related, and by convergence such acquisition in forms which are not closely related." This observation leads the author to "emphasize the necessity of founding schemes of classification upon the totality of structure, and of determining the value of characteristics, whether they are primitive or acquired, divergent, parallel, or convergent, before attempting to assign them their proper taxonomic value."

H. S. W.

4. *The Dinosaurs of North America*; by O. C. MARSH. Extract from the Sixteenth Annual Report of the U. S. Geological Survey, pp. 133-414, 66 cuts in text, plates ii-lxxxv. Washington, 1896.—The Dinosaurs are by far the most prominent group of vertebrates of geologic times, excelling all other groups, not only in size, but also in degree of specialization. Their development is confined strictly within the limits of the Mesozoic, and, therefore, in tracing their history through the Triassic, Jurassic, and Cretaceous, their rise, culmination, decline, and extinction are fully recorded.

In the present memoir, the arrangement of the subject is mainly geological. The Dinosaurs are recognized as a subclass, embracing the three orders *Theropoda*, *Sauropoda*, and *Predentata*. Of these, the first were carnivores and the others herbivores. The *Predentata* are again divided into three suborders: (a) the *Stegosauria*, Dinosaurs more or less protected with dermal plates; (b) the *Ceratopsia*, huge horned forms; and (c) the *Ornithopoda*, Dinosaurs with bird-like characters.

In the Triassic, all the best-known species belong to the carnivorous order *Theropoda*. Abundant evidences of the herbivorous forms are found in the footprints so common in the Connecticut sandstone, but as yet no distinctive teeth or bones have been discovered there.

Among the Jurassic Dinosaurs, the diminutive *Hallopus*, the small *Cœlurus*, and the ferocious *Allosaurus* and *Ceratosaurus* are

the chief representatives of the *Theropoda*. The order *Sauropoda* is confined to the Jurassic, and contains some most striking forms. Among them, *Atlantosaurus*, *Brontosaurus*, *Apatosaurus*, *Diplodocus*, and *Morosaurus* are remarkable for their huge size. The *Preidentata* of the Jurassic include the well-known *Stegosaurus*, and the bird-footed genera *Camptosaurus*, *Laosaurus*, and the smallest of known Dinosaurs, *Nanosaurus*.

Dinosaurs were still abundant in the Cretaceous, and in general were more highly specialized than in the preceding formations. *Ornithomimus*, with its bird-like feet and the coössified pelvic arch, is one of the most important carnivores. The main interest in the Cretaceous Dinosaurs centers about the most remarkable group of gigantic, horned *Preidentata*, known as the *Ceratopsidae*, including *Triceratops*, *Ceratops*, *Torosaurus*, *Styracotholophus*, *Agathaumas*, *Polyonax*, and *Monoclonius*. The remaining herbivorous forms include the *Claosauridae*, *Trachodontidae* (*Hadrosauridae*), and *Nodosauridae*.

The more important bones of the skeleton of each type are fully illustrated, and the best-known forms are represented by complete restorations: such as *Anchisaurus* of the Triassic; *Ceratops*, *Brontosaurus*, *Stegosaurus*, *Camptosaurus*, and *Laosaurus*, of the Jurassic; and *Triceratops* and *Claosaurus* of the Cretaceous.

Restorations of four leading types of European Dinosaurs are introduced for comparison: *Compsognathus*, a small carnivore; *Scelidosaurus*, a herbivorous form related to *Stegosaurus*; *Hysilophodon*, related to *Laosaurus*; and *Iguanodon*.

A separate chapter is devoted to the affinities of the Dinosaurs, and homologies are established with the *Aëtosauria*, the *Belodontia*, the *Crocodylia*, and with Birds. In the concluding chapter, a classification of the entire group is presented.

C. E. B.

5. *Manual of Determinative Mineralogy with an introduction on Blow-pipe Analysis*; by GEO. J. BRUSH, revised and enlarged by SAMUEL L. PENFIELD, 8vo, 163 pp., 33 tables. New York, (Wiley & Sons), 1896.—That this well known work has been appreciated by the public is shown by the fact that the present is the fourteenth edition since its appearance in 1874. The present edition by Prof. Penfield is not, however, a merely formal one; on the contrary, the book, while retaining all the features which have characterized and given it its value, has been for the most part rewritten, and considerably enlarged. Especially valuable to teachers and self-students will be found the chapter on the reactions of the elements; many new methods of testing are here added. The distinguishing feature of the work is its eminently practical character; in all cases the most simple, useful and decisive methods are given; there is no padding with descriptions of complicated methods or those which have only a theoretic interest. The suggestions given under the experiments will be of great value. The work throughout shows that it comes at first

hand from the teacher and investigator, and nowhere does one find the vagaries of indiscriminate compilation, which are an all too common fault in books of this character. The tables are those of the former edition, but a revision of them also is promised for the near future.

L. V. P.

6. *Mikroskopische Physiographie der massigen Gesteine* von H. ROSENBUSCH. 3d ed. enlarged and revised, 8vo, second half, pp. 553-1360. Stuttgart 1896.—The appearance of the new edition of this well known work has already been noticed in this Journal (vol. i, p. 63, 1896); the issuance of the second part completes it. The present part contains the effusive rocks, in which the age distinction in classification is retained. The later rocks are, however, described first as being the most typical, and it is clear that the author does not attach the importance to age that the separation in the book would seem to imply. The important group of diabases are described in this part. New matter has been everywhere added and the subject dealt with critically to date. The excellent indices are especially to be commended, greatly aiding as they do in ready reference. It is to be regretted that the size of the volume necessitated the omission of the general index to the literature, which was so serviceable a feature of the previous editions.

L. V. P.

7. *Die Minerale des Harzes*, eine auf fremden und eigenen Beobachtungen beruhende Zusammenstellung der von unserem heimischen Gebirge bekannt gewordenen Minerale und Gesteinsarten von DR. OTTO LUEDECKE. 643 pp. with an atlas. Berlin, 1896 (Gebrüder Borntraeger).—The mining region of the Harz Mountains in Germany is one that has long been classical in the study of mineralogy, remarkable both for the number of the species it has afforded and for the perfection in which many of them have been found. The author states that he has devoted himself to the study of this region since 1880, and in addition to his own extensive collections he has had the use of a number of other collections, public and private; the material at his disposal has thus been very large. The results of his labors, in part previously published, are given in this large volume. To his own observations he adds also a summary of the earlier literature and of the work of other mineralogists, and the volume thus becomes a complete monograph of a series of most important mineral localities. The species are arranged according to the usual chemical classification and under each is given a minute account of its crystallization, method of occurrence and association with other species. In special cases, as for example with galena and chalcopyrite, the feldspars, etc., a more minute geological description is given of the particular regions involved, as also of the associated rocks.

The thoroughness with which the author has performed his work, and the admirable way in which the whole is presented, makes the volume one of very great value. A series of some twenty-seven plates give figures of notable species, with spher-



ical projections in many cases, a chart of the whole region showing all the mineral veins is added and special ones for Clausthal and Andreasberg.

8. *Minéralogie de la France et ses colonies*; description physique et chimique des minéraux; étude des conditions géologiques de leur gisements, par A. LACROIX; tome deuxième, 1re partie, 352 pp.; Paris, 1896 (Baudry et Cie.).—The part now published of the *Mineralogy of France* forms the first portion of the second volume, and is largely given up to a description of the feldspars, including also the zeolites and related species. The special character of this admirable work has been dwelt upon in the notices of the volume which have appeared earlier. The author states that the work has grown on his hands and that when completed it will include another volume beyond what was previously promised. The minute description of the occurrence of the different species which each locality considered gives the work a unique character among mineralogical publications. The fact that the author has himself visited the greater part of the localities mentioned has enabled him not only to present many new facts, but to give a detailed and thorough account of each occurrence with the special geological conditions characterizing it. The work is hence quite as interesting and important for the geologist as the mineralogist.

9. *The Vienna Collection of Meteorites*.—The tenth volume of the "Annalen des K. K. naturhistorischen Hofmuseums" contains an exhaustive account of the collection of meteorites at the Vienna Museum, prepared by Dr. Brezina, until recently the Custos. The collection is probably the largest and most richly represented among those in the great museums of the world. The number of separate occurrences recorded is 498, and the list includes about 60 more which are not represented at Vienna. Many of the specimens are of extraordinary interest and not a few are entirely unique, as for example, the iron of Mazapil, Mexico, and that of Cabin Creek, Arkansas, both purchased from collectors in this country.

As the result of his study of meteorites, Dr. Brezina classifies them into the two grand groups, I, of the stony meteorites, and II, of iron meteorites, according as to whether the silicates or the metallic constituents predominate. Further, he recognizes under these groups six sub-groups, with a seventh which is intermediate between them. He names them as follows: A. Achondrites, including stones with but little iron and in which the chondrules are essentially absent. B. Chondrites, consisting of bronzite, olivine, and nickel-iron with round or polyhedral chondrules. The third sub-group, C. Sideroliths, forms the transition to the irons, including those in which olivine and bronzite are prominently present and in a cross-section seem to separate the iron into individual grains. Under the iron meteorites we have next D. Lithosiderites, in which silicates in the form of crystalline grains are imbedded in a continuous mass of iron (here fall the

pallasites). Further, E. Octahedrites, or irons with octahedral structure; F. Hexahedrites or cubic irons, and finally, G. Ataxites, or those in which the iron is closely compact and does not show the crystalline structure characteristic of E and F. These groups are further divided into sixty-one classes, under each of which the specimens belonging to it are given and its peculiar features described, often with illustrations. This catalogue is a highly important contribution to our knowledge of meteorites in general.

10. *Phosphate deposits in Tennessee*.—Prof. J. M. SAFFORD has recently described a new occurrence of phosphate rock in Central Tennessee, which promises to be of much economic importance. The locality now opened is in the town of Mt. Pleasant, in Maury County, where the phosphate is found in banks from three to eight feet in vertical thickness. The rock is light yellowish or grayish in color, of an open, spongy structure, and occurs in layers or plates from one to six inches or more in thickness piled together in stratified masses. Analyses show that it consists of from 60% to 80% of calcium phosphate, with calcium carbonate, etc.

This phosphate rock has been derived from limestone of Trenton age, particularly the "Capitol limestone," through a long continued process of leaching by carbonated waters, which have dissolved away the calcium carbonate and left the less soluble layers of phosphate. The source of the phosphate in the original limestone is yet in doubt.—*Amer. Geol.*, Oct. 1, 1896.

11. *National Academy of Sciences*.—The following is a list of the papers presented for reading at the meeting of the Academy held at New York, Nov. 17 and 18:

A. MICHAEL: On certain positive-negative laws in their relation to organic chemistry.

O. C. MARSH: The Jurassic formation on the Atlantic coast.

IRA REMSEN: The hydrolysis of acid amides. The isomeric chlorides of parani-troorthosulphobenzoic acid.

ALFRED M. MAYER: The equations of the forces acting in the flotation of disks and rings of metal, with experiments showing the floating of loaded disks and rings of metal on water and on other liquids.

E. D. COPE: On the geographical distribution of Batrachia and Reptilia in the Medicolumbian region.

S. NEWCOMB: On the physical causes of the periodic variations of latitude. On the solar motion as a gauge of stellar distances.

C. A. WHITE: Memoir of F. B. Meek.

A. E. VERRILL: The evolution and pylogeny of Gastropod Mollusca.

O. N. ROOD: On flicker photometers.

C. S. HASTINGS: A new type of telescope free from secondary color.

C. S. PEIRCE: A graphical method of logic. Mathematical infinity.

## III. BOTANY.

1. *The Timber Pines of the Southern United States*; by CHARLES MOHR, PH.D. Prepared under the direction of B. E. Fernow, Chief of the Division of Forestry, U. S. Dep. of Agriculture, Washington, D. C. 1896.

Four species of pines in our Southern States possess a high degree of interest from an economic point of view. It is to these pines that we look for a large part of our supply of lumber, especially as the threatened diminution of our northern resources is already upon us. In these pineries prompt application of sound principles of forestry may check unnecessary waste and bring permanent thrift where one can now see little but prodigal and irrational treatment.

It is difficult to see how the importance of this question can be brought fairly before those who are primarily concerned in lumbering operations. The lumberman is so apt to regard his forests as a source of immediate profit, that he finds it almost impossible to treat them as a source of permanent income. In some instances he would indeed be willing to exchange the larger immediate profit for the smaller permanent income, but he knows that under existing conditions there are risks, like that of fire, for instance, which lessen the stability of his investment. And therefore even the cautious and far-seeing lumberman takes the bird in the hand instead of the possible two in the bush. Conditions of scientific lumbering at the south are more favorable than at the north, but scientific lumbering is not forestry. The forester is the husbandman of wood crops: the lumberman is merely a harvester. The question is, therefore, how can the harvester be made to see that it is for his interest to take part in the care as well as the cutting. Professor Fernow, the chief of the Forestry Division of the Department of Agriculture, has deemed it wise to bring to the attention of the owner of the southern pineries Dr. Mohr's monograph on the life-history of the five principal species, supplementing this by an account of the structure of the wood by Mr. Roth. Of course we cannot say that the experiment will be any more successful than a hundred others which have been undertaken in Forestry instruction, but we can say that the experiment ought to succeed, and we give it our best wishes.

The monographs are valuable contributions to our knowledge of the subject and should serve a good purpose. Dr. Mohr has displayed great energy in his accumulation of material and excellent judgment in its treatment. We wish it might be possible for him to continue his exhaustive and scholarly studies in similar directions until all our timber trees of economic importance are as well understood as these five which he and Mr. Roth have examined so thoroughly.

The sumptuous work on our native trees by Professor Sargent,

AM. JOUR. SCI.—FOURTH SERIES, VOL. II, No. 12.—DECEMBER, 1896.



"The Silva," now publishing, deals to some extent with the economic aspects of our timber trees and in a judicious manner. Such treatises as that by Dr. Mohr supplement "The Silva" in the best possible way, and make, with that, a firm basis for a wise and fruitful Forestry.

G. L. G.

2. *Richards on increase of activity in respiration after injury.*—Professor PFEFFER gave, at the July session of the Leipzig Academy, an account of certain experiments on living plants conducted by Dr. H. M. Richards, in his laboratory. These traumatic reactions both as regards respiration and temperature are decided. Dr. Richards has taken up the subject about where it was left by Böhm and Stich, and has made substantial additions to our knowledge. The most telling experiments were performed on fleshy and rather fully developed organs, where as a consequence of wounds, there would be an increase in the rate of respiration amounting to even twenty fold.

G. L. G.

#### OBITUARY.

BARON FERDINAND VON MUELLER, K.C.M.G., Government Botanist of Victoria, died at Melbourne on October 9th, in his seventy-second year. After completing his studies at Kiel, he went to Australia, very largely on account of his health, and soon engaged in the exploration of his new home. His tastes led him early to collect and examine the plants of Australia, and to this task he devoted the remainder of his life. He took particular interest in the economic advancement of his own colony and contributed much to this phase of development in all parts of Australia. His voluminous writings have enriched almost every department of botany and constitute an enduring monument. The present writer made the Baron's personal acquaintance in Melbourne in December 1890, and from that date to this has had very frequent opportunities of noting the goodness of heart by which all controversies were tempered. The Baron felt himself deeply aggrieved at his treatment at the hands of certain public officials in the Colony, but this did not prevent his devoting all of his slender means and all his energies to what he regarded sound and healthy development of his adopted land.

It is pleasant to note that his scientific associates in Australasia, although differing widely from him as to many questions of public policy and scientific interpretation, willingly paid him the honor of electing him in 1889 the presidency of their Association for the Advancement of Science. At the next meeting of the Association, at Christ Church, New Zealand, Baron Mueller had the deep satisfaction of renewing friendly relations with some from whom he had been long estranged, and from that period to the end of his useful life, his arduous labors were lightened by additional reconciliations. Much if not all the old bitterness of real and fancied wrongs had passed away.

G. L. G.

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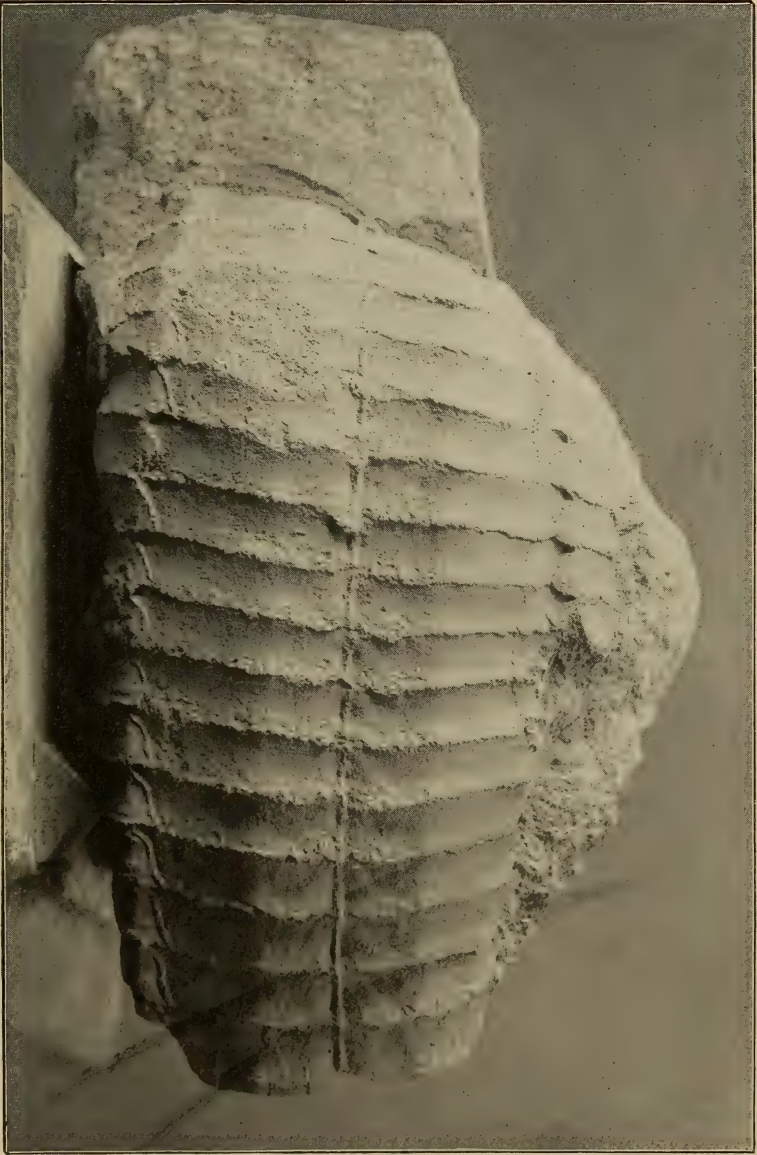
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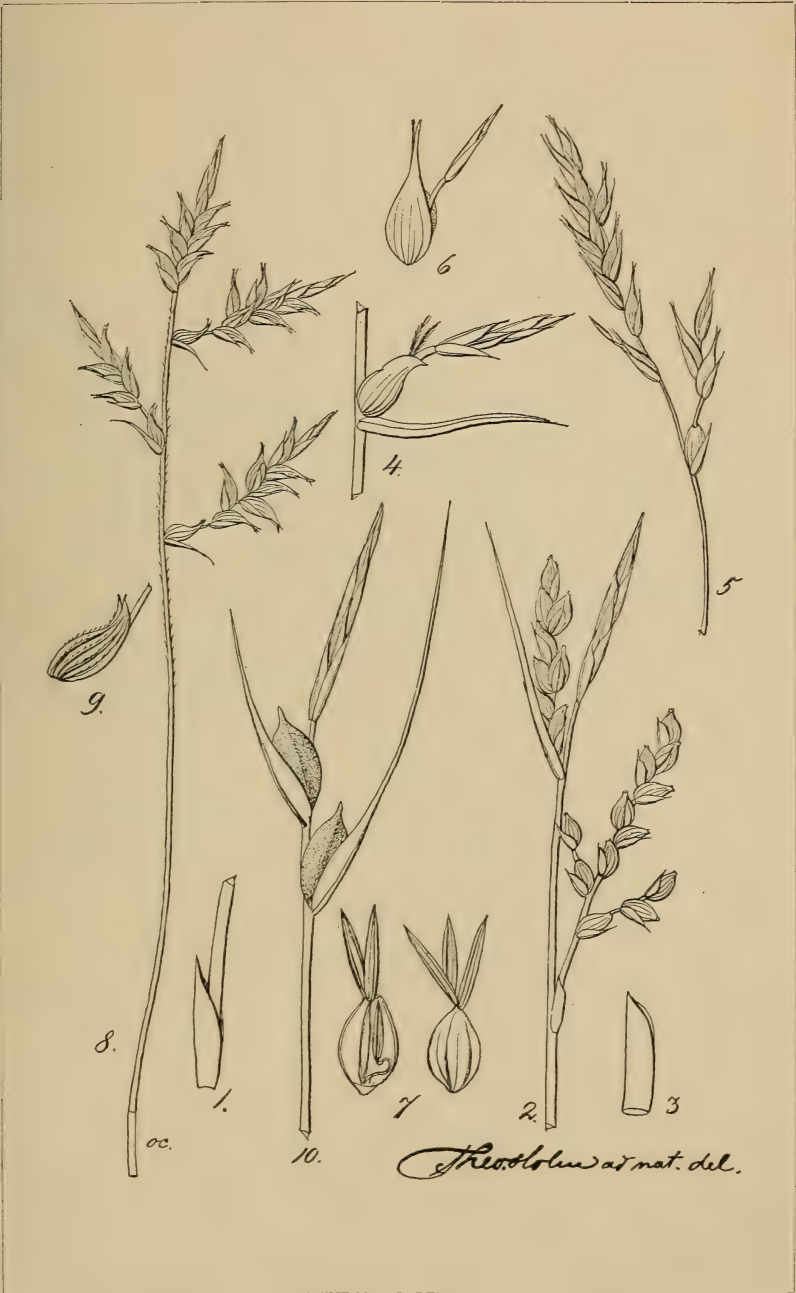




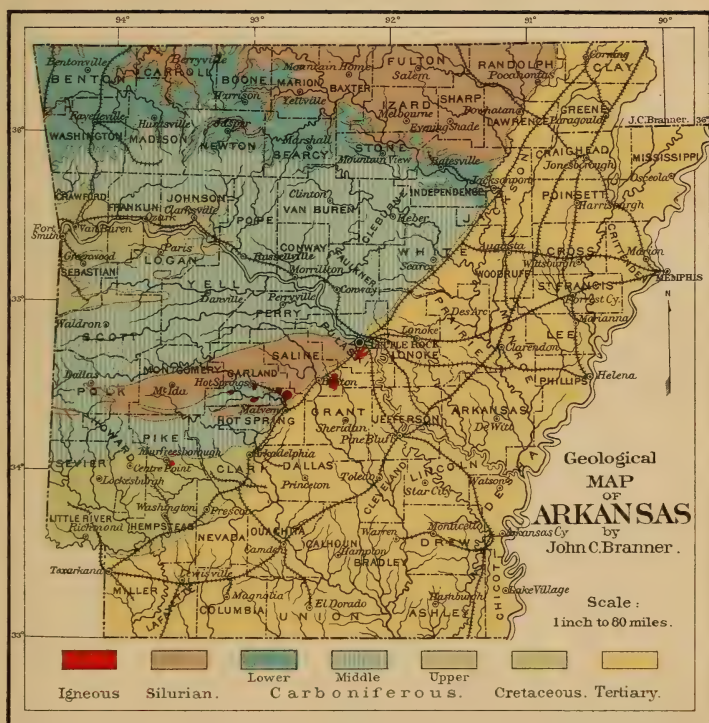
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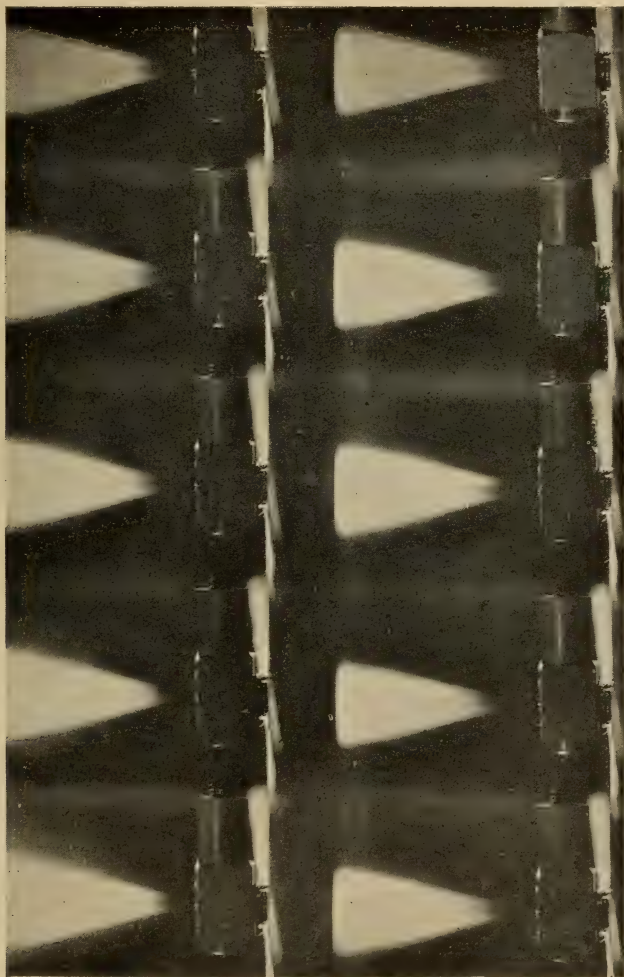




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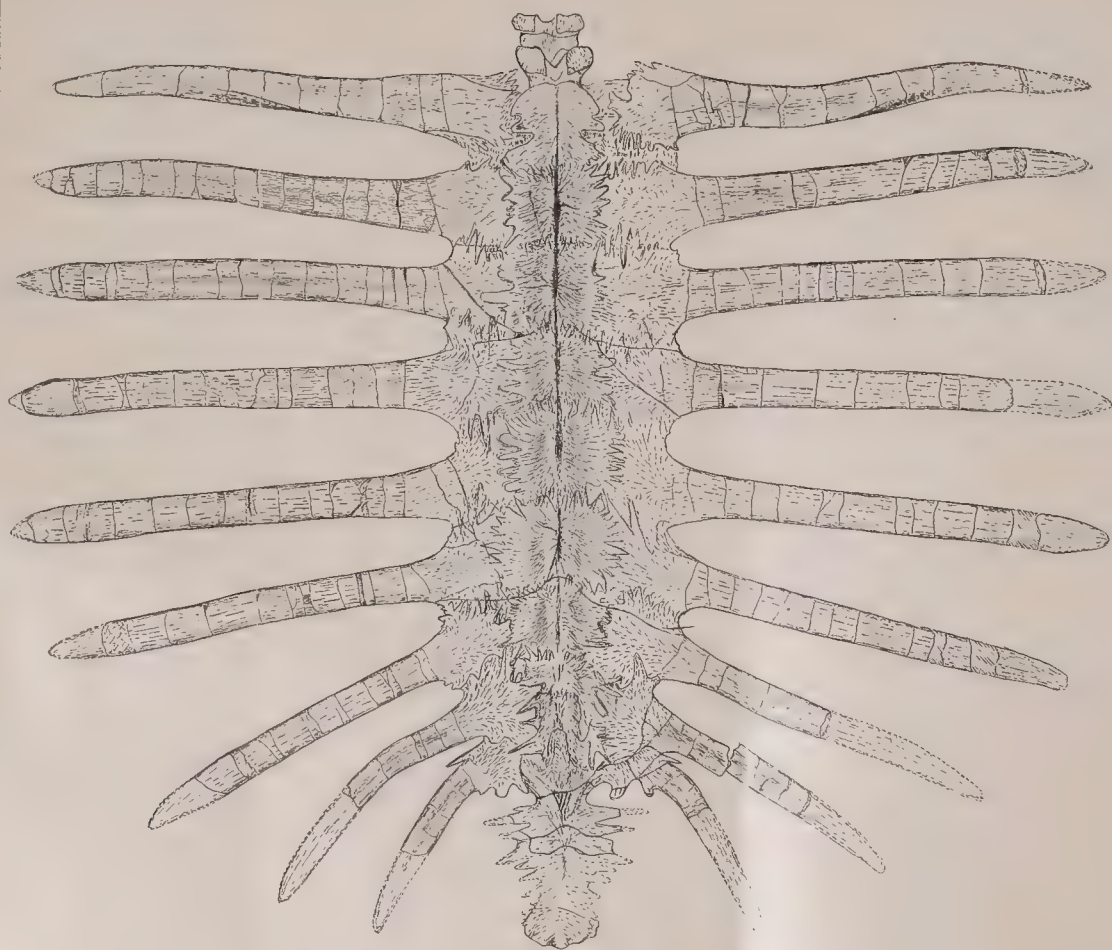
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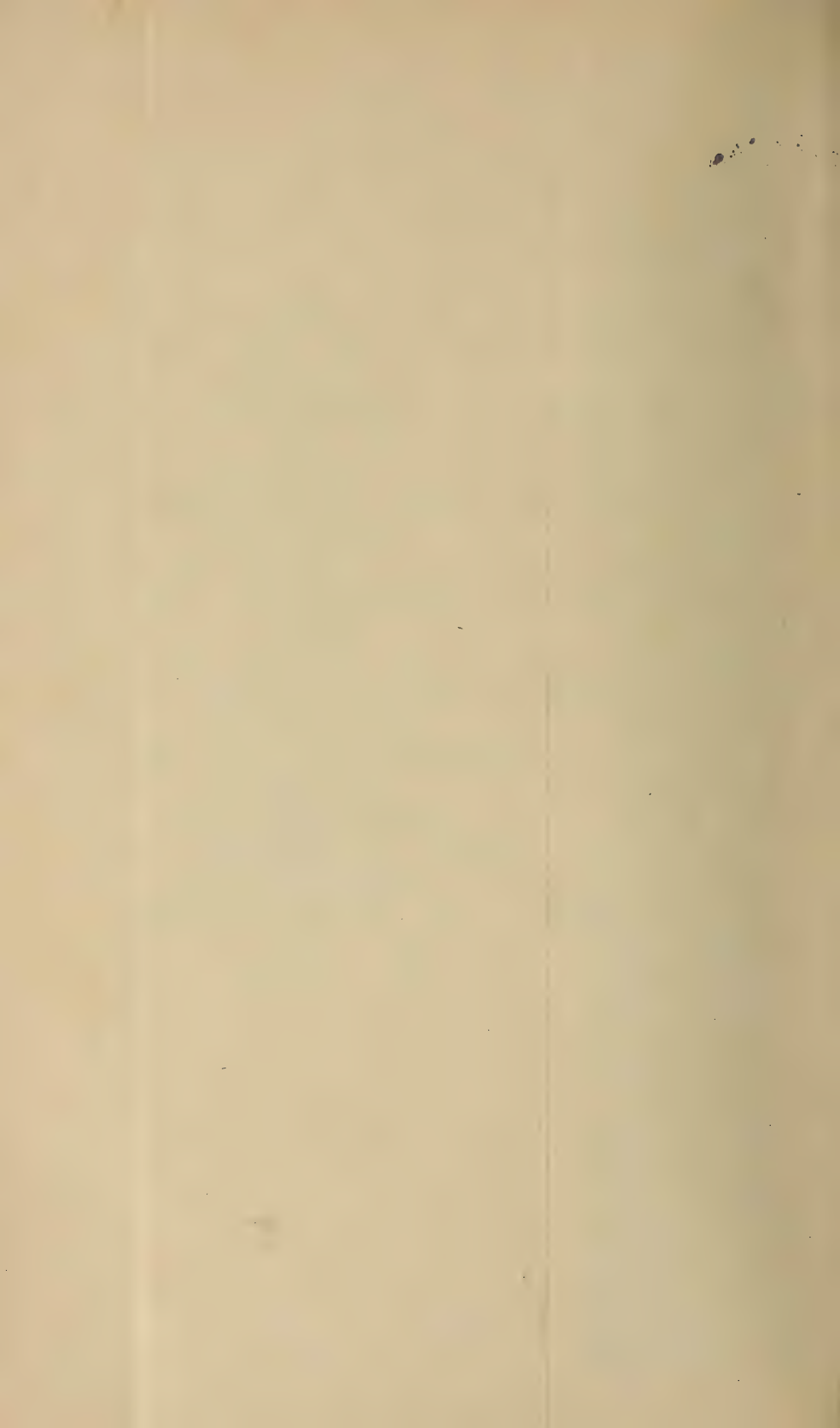






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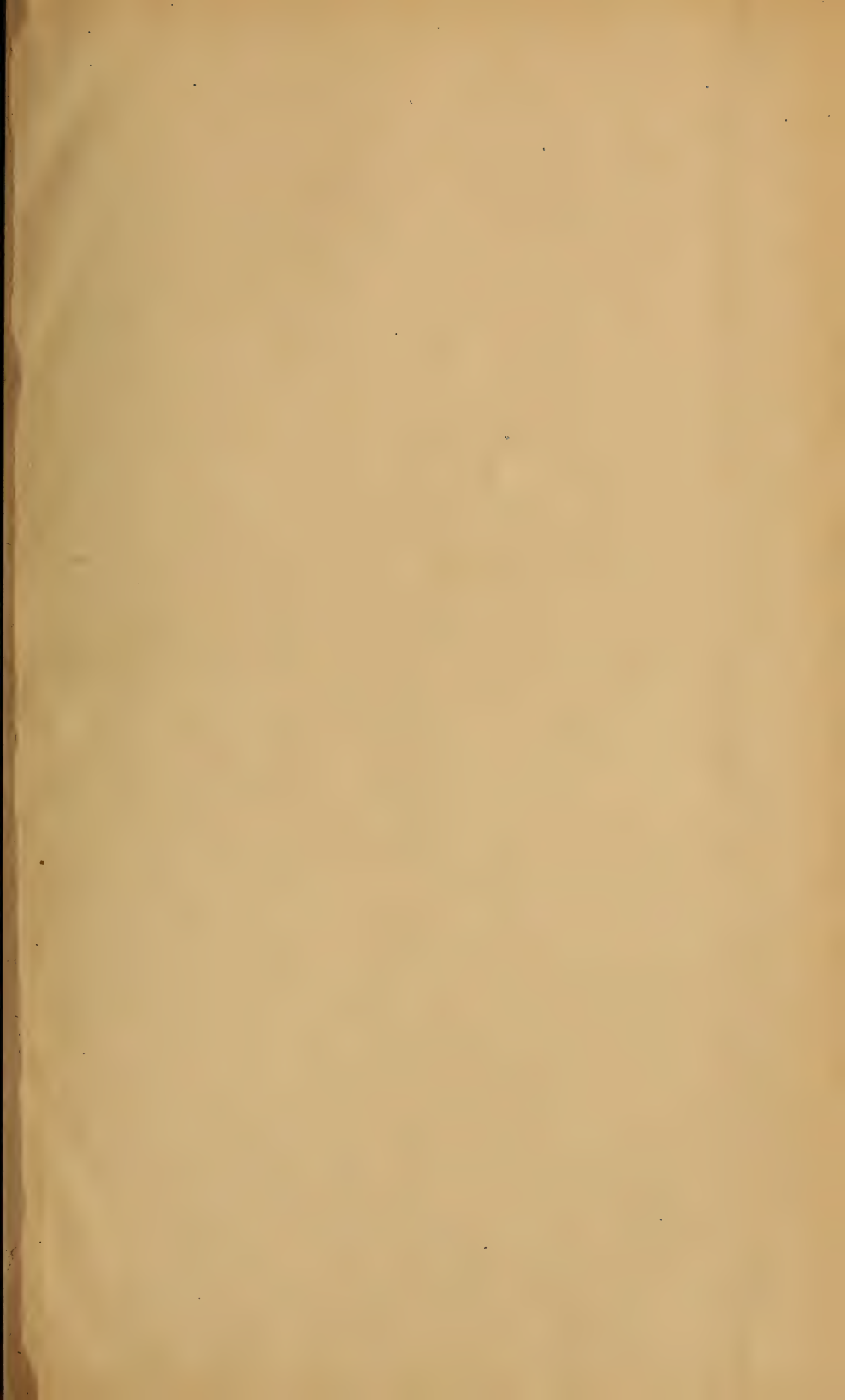
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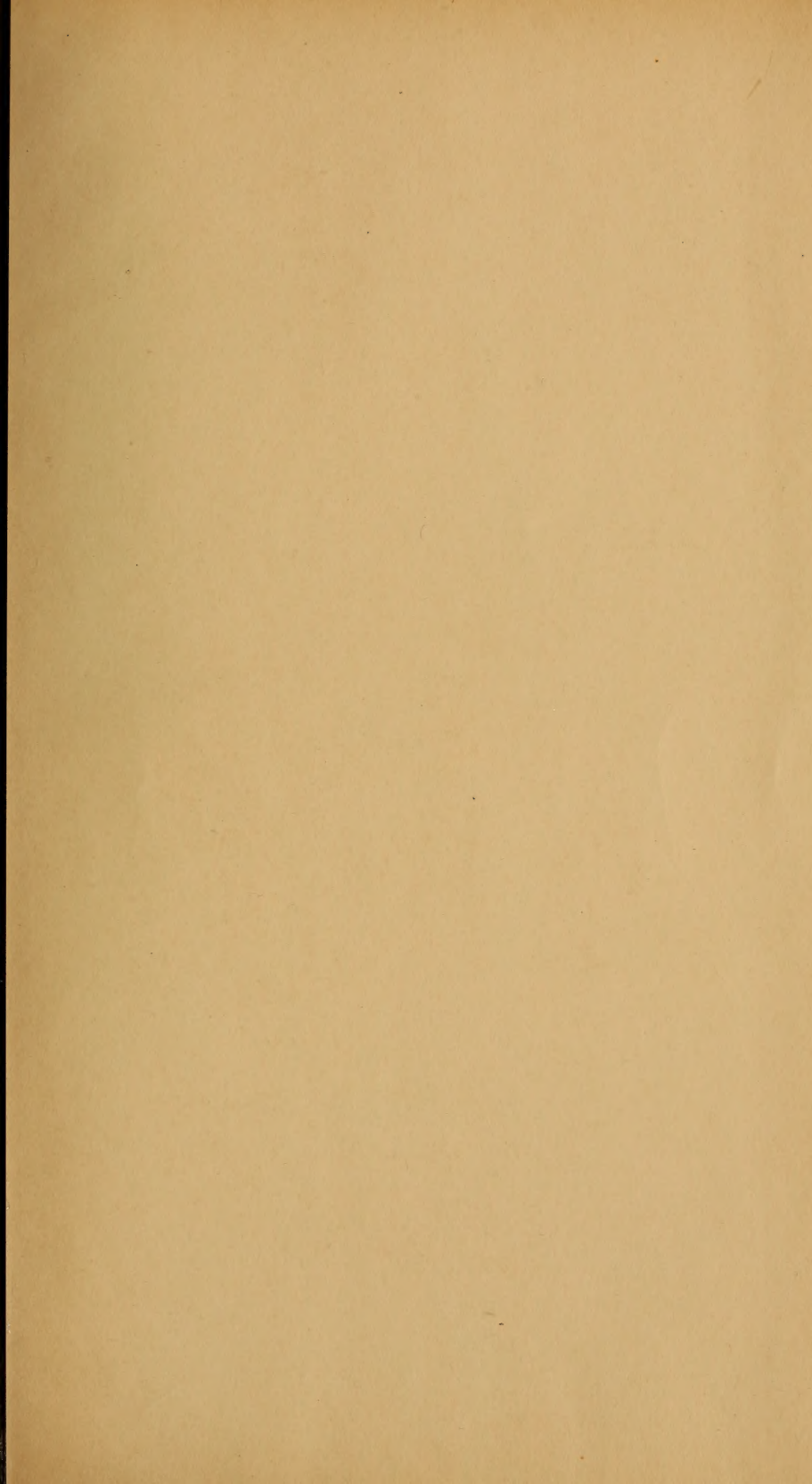




















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